(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
17 May 2001 (17.05.2001)

PCT

(10) International Publication Number
WO 01/35329 A1

(51) International Patent Classification[7]: G06K 11/18

(21) International Application Number: PCT/IL99/00601

(22) International Filing Date: 8 November 1999 (08.11.1999)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: ITPEN LTD. [IL/IL]; c/o Avishai Berkovitz, Attorney, Jabotinsky Street 155, 52575 Ramat Gan (IL).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: SHOLEV, Mordehai [IL/IL]; 37830 Amikam (IL).

(74) Agents: LUZZATTO, Kfir et al.; Luzzatto & Luzzatto, P.O. Box 5352, 84 152 Beer Sheva (IL).

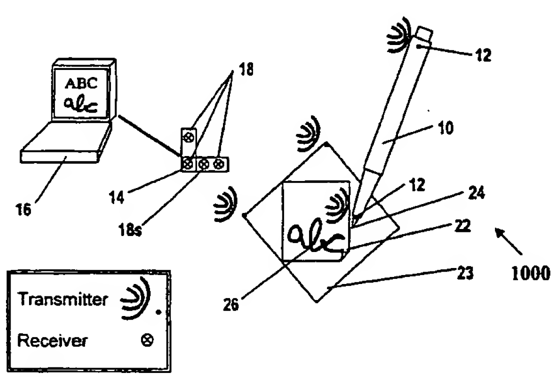
(81) Designated States *(national)*: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: APPARATUS FOR DIGITIZING WRITING AND DRAWING WITH ERASING AND/OR POINTING CAPABILITY



(57) Abstract: Method and system for acquiring a graphical representation of one or more intersection points between a straight line and a surface (23) having a known location and orientation. Transmission from two or more aligned transmission points (12), being in any desired spatial orientation is received in a set of receivers (18). The transmission points (12) lie substantially along the straight line, and each transmission point (12) is separated from its neighboring point(s) (12) by a first fixed distance. The spatial coordinates of at least two transmission points (12) are determined by receiving signals transmitted from these transmission points (12) in the set of receivers (18), and processing the received signals. A at least one characteristic point (24) being co-linear with the transmission points (12), and separated from at least one transmission point (12) by a second fixed distance, is determined. The spatial coordinates of this characteristic point (24) are calculated using the spatial coordinates of the two transmission points (12), and the second fixed distance, and the spatial representation of the surface (23) is determined and/or calculated. Whenever the straight line and the surface (23) intersect, the spatial coordinates of the intersect point are calculated. A first graphical representation, indicating coincidence between the intersect point and the characteristic point (24), and a second and different graphical representation, indicating lack of coincidence, are displayed on a graphical representation of the surface (23).

WO 01/35329 A1

APPARATUS FOR DIGITIZING WRITING AND DRAWING WITH ERASING AND/OR POINTING CAPABILITY

Field of the Invention

The present invention relates to the field of the digitization of writing and drawing. More particularly, the invention relates to method and apparatus for acquiring a computerized representation of a trace and/or movements of a selected point, made according to the relative displacement between the tip of an elongated device, e.g., a writing/drawing instrument, and a support, by receiving signals transmitted from two or more aligned points along the device, and calculating the spatial position of the tip.

Background of the Invention

Computerized graphical representation of manual traces, such as hand-writing and/or drawing, is widely used by artists and designers. Accurate reproduction of lines and figures made by free-hand provides many features to the designer, who can store the original trace, and further process the drawn lines by using software. For example, the original trace can be sketched by hand in black and white, and can be painted or modified later by the designer or by another person, to obtain the final design. In many applications, such computerized reproduction should be sufficiently accurate, so as to capture the original design. In addition, the designer often is used to draw traces with a conventional utensil, and therefore an accurate simulation of the trace made by the movement of its tip is highly desired. Other applications also require erasing capabilities, which provide the designer more flexibility to make modifications in the drawn trace.

A widely used type of a two-dimensional input devices is a "mouse", connected to a workstation. Mice are connected directly to the computer, usually via a cable, or may use wireless data connection. A typical mouse comprises a round ball on its bottom, designed to roll along a desktop or pad

near the computer. When the mouse is moved, it provides a signal to the computer which moves the cursor on the monitor of the computer in the same direction. However, this type of mouse only provides data associated with a relative movement, rather than an absolute location and therefore, the continually provides position change information. Furthermore, the shape of the lower surface of a typical mouse is flat and relatively large, making it difficult to use for free-hand writing.

Another widely used type of input devices is a stylus shaped pen (or the like) and tablet device. The tablet, which comprises digitizing means (such as optical means, magnetic induction means or grid) thereon, is connected to the computer, and may further comprise a paper attached to the writing-surface of the tablet. The user moves the pen freely, while providing input to the computer whenever the pen touches the tablet. However, the absolute two-dimensional position provided to the computer by the combination of a stylus shaped pen (or the like) and tablet is confined to the space of the tablet.

Another type of input devices are three-dimensional input devices. U.S. Patent 5,144,594 to Gilchrist describes an acoustic mouse system which controls indications on a two-dimensional (X-Y) surface. It comprises a support for holding three acoustic receivers in a plane and a pen-like device having an acoustic transmitter therein. The three-dimensional (X-Y-Z) location of the pen-like device is determined by the receivers in response to signals from the transmitter. The X-Y location is utilized to locate a cursor on the monitor of the computer and the Z direction location is utilized to change the display, such as controlling the presentation of different windows on the monitor.

U.S. Patent 5,012,049 to Schier describes a position determining apparatus having embodiments providing two-dimensional and three-dimensional

position information. The apparatus comprises a pen-sized movable transmitting device and a plurality of receivers, where the transmission is of pulses of laser light. For determining two-dimensional position, the apparatus has three receivers located in a line and the transmitting device has one or two transmitters. For determining three-dimensional (3-D) position, the apparatus has two transmitters and four receivers, three of which are coplanar and the fourth is in a non-coplanar relationship with the other three. However, this apparatus can only measure locations within the space defined by the receivers.

Position determining apparatus are also utilized as position measuring devices. U.S. Patent 3,924,450 to Uchiyama et al describes a device for measuring coordinates of models. It comprises a supersonic transmitter located somewhere on the model and three supersonic receivers located in space. The transmitted signal, when analyzed, provides the location of the transmitter on the model. In one embodiment, two transmitters are placed on a pointing device. The initial location of the point of the device is known with respect to the locations of the transmitters. Thus, the position of the point can be determined from the location of each transmitter. However, this device does not provide and writing and/or drawing capability.

US Patent 5,517,579 to Baron discloses a handwriting recognition apparatus which comprises an input apparatus employing two different sensing techniques to sense handwriting, and a symbol identification apparatus, which receives the output of the input apparatus and provides an output indication of symbols represented by the handwriting. However, the disclosed apparatus does not digitize the trace generated by the handwriting, but rather transforms it into a predetermined symbol. In addition, this apparatus does not have any erasing capabilities.

US Patent 5,717,168 to DeBuisser et al. discloses an instrument for capturing and processing graphical information by using two ultrasound transmitters attached to the instrument and substantially aligned with its tip. Three or more receivers are used to receive ultrasound pulses, transmitted from the instrument and from additional transmitters located on a support on which a trace is made, and to evaluate therefrom the position of the tip on the support. However, the tip of this instrument can not be used for writing on the surface of the support, and therefore the drawn trace is visible only after simulation. In addition, no erasing features are provided by the instrument, and can be done only by software.

A sonic digitizer (manufactured by GTCO Calcomp Inc., Columbia MD, USA) which calculates the 3-D coordinates of a pointer is disclosed. The digitizer collects 3-D data which is processed and gathered, so as to build virtual plants. However, this device also does not provide and writing and/or drawing capability, and cannot be used as a mouse.

All the methods described above have not yet provided satisfactory solutions to the problem of acquiring an accurate computerized graphical representation of a visible trace, made according to the relative movement between the tip of an elongated writing/drawing instrument, and a support, with erasing capabilities.

It is a primary object of the present invention to provide apparatus by means of which an accurate spatial position of a point located on an elongated device can be determined in cooperation with computing means.

It is an object of the present invention to provide an apparatus for acquiring an accurate computerized graphical representation of a real trace, which overcome the drawbacks of the prior art.

It is another object of the present invention to provide an apparatus for acquiring an accurate computerized graphical representation of a real trace, which is easy to use in free-hand.

It is a further object of the present invention to provide an apparatus for acquiring an accurate computerized graphical representation of a real trace, which also provides erasing capabilities.

It is still another object of the present invention to provide an apparatus for acquiring an accurate computerized graphical representation of a real trace, which provides unique attributes of the real trace.

It is yet another object of the present invention to provide an apparatus for acquiring an accurate computerized graphical representation of a real trace, which enables the support, on which the trace is drawn to be in any spatial position.

It is still another object of the present invention to provide an apparatus for acquiring a three-dimensional accurate computerized graphical representation of a real trace, which enables the support, on which the trace is drawn to be convex or concave.

Other objects and advantages of the invention will become apparent as the description proceeds.

Summary of the Invention

The present invention is directed to a method for determining spatial and/or planar position of a point. Two or more transmitters are positioned substantially along a straight line passing through the point, the position of which it is desired to determine. The position is calculated using the

position of the two or more transmitters, the distance between them and the distance between the point and one of the transmitters. A method for determining spatial and/or planar position of a point comprising positioning two or more transmitters substantially along a straight line passing through the point, the position of which it is desired to determine, and calculating the position using the position of the two or more transmitters, the distance between them and the distance between the point and one of the transmitters. A graphical representation of one or more intersection points between a straight line and a surface having a known location and orientation is acquired. Transmission is received from two or more aligned transmission points being in any desired spatial orientation, each transmission point being separated from its neighboring point(s) by a first fixed distance. The transmission points are lying substantially along the straight line. The spatial coordinates of at least two transmission points are determined by receiving a signal transmitted from the at least two transmission points in a set of receivers, and the signal is then processed. At least one characteristic point being co-linear with the transmission points is determined, and separated from at least one transmission point by a second fixed distance. The spatial coordinates of the characteristic point are calculated using the spatial coordinates of the at least two transmission points and the second fixed distance. The spatial representation of the surface is determined and/or calculated. Whenever the straight line and the surface intersect, the spatial coordinates of the intersect point are calculated. A first graphical representation indicating coincidence between the intersect point and the characteristic point, and a second and different graphical representation indicating lack of coincidence are displayed on a graphical representation of the surface.

The characteristic point may represent the location of a tip of an elongated instrument, the longitudinal axis of which essentially coincides with the calculated straight line. Preferably, whenever there is coincidence between

the intersect point and the characteristic point, the instrument is used as a utensil by exploiting the tip for writing/drawing on the surface, a trace being reproduced on a display and/or in a data storage means by the graphical representation according to the relative movement between the tip and the surface. Whenever there is coincidence between the intersect point and the characteristic point, the instrument is used as a utensil by exploiting the tip for erasing from the surface, a portion of a drawn trace which is reproduced on a display and/or in a data storage means by the graphical representation, by removing a corresponding portion from the graphical representation according to the relative movement between the tip and the surface. Preferably, the instrument is used as a utensil by exploiting a combination of a writing/drawing tip at one end of the utensil, and an erasing tip at the opposing end of the utensil. Whenever there is no coincidence between the intersect point and the characteristic point, the instrument is used as a pointer by exploiting the proximal tip for pointing on the surface towards the intersection point, and reproducing the intersection point on a display of the surface by a corresponding graphical representation. While pointing a light beam is directed from the proximal tip towards the intersection point.

According to a preferred embodiment of the invention, each transmission point contains a transmitter, or an antenna, into which power is switched from a distal transmitter. The transmitted signal may be an RF signal, an IR signal or an ultrasonic signal. Preferably, the surface can be moved and/or its orientation can be varied without affecting the acquired representation by performing the following steps:

a) receiving transmissions from two or more transmission points located on the surface and in any desired spatial orientation;

b) calculating the spatial coordinates of each point on the surface in any location and spatial orientation;

c) obtaining information related to any undesired change in the

coordinates of the calculated intersect point caused by relative movement and/or relative change in orientation of the surface; and

d) compensating for the undesired change prior to displaying the graphical representation.

Discrimination between writing/drawing and erasing operations of the utensil is obtained by assigning a unique code to the proximal transmission point closest to the writing/drawing tip, a unique code to the distal transmission point closest to the erasing tip. The codes from the proximal and distal transmission points are received and their spatial coordinates are calculated. The utensil is operated in its writing/drawing mode whenever the tip closer to the proximal transmission point coincides with the surface, and in its erasing mode, whenever the tip closer to the distal transmission point coincides with the surface.

Preferably, the proximal tip or the distal tip are used to point toward the surface, so that the displayed graphical representation of the intersect point coincides with another displayed graphical representation of an object. While keeping the proximal tip or the distal tip directed to the intersect point, a predetermined characteristic signal is emitted from one or more transmission points and the characteristic signal is received in the set of receivers and in response, the displayed object is selected. The graphical representation of the selected object can be manipulated by changing the intersection point. Manipulation comprises mouse operations and/or executing a program linked to the selected object.

Preferably, the spatial coordinates of the intersect point are obtained by calculating the cross product between a first vector, extending from a selected transmission point on the surface to another transmission point on the surface, and a second vector extending from the selected transmission point on the surface to the intersect point. The spatial coordinates of the

intersect point are obtained by performing the following steps:

a) calculating the projections of the first and of the second fixed distances on a first selected two dimensional plane and obtaining a coordinate which corresponds to one dimension of the first selected plane; and

b) calculating the projections of the first and of the second fixed distances on a second selected two dimensional plane and obtaining the two remaining coordinates which correspond to the dimensions of the second selected plane.

The data received by the set of receivers can also be processed and/or displayed at a remote station, such as a fax machine, a computer or a cellular phone, linked to the set of receivers via a data link. Data can be transferred through the data link over a telephone line and/or a cellular phone system, or via an E-mail system.

Preferably, the handwriting of a specific user operating the writing/drawing utensil can be characterized by performing the following steps:

a) enabling the tip to move along the axis which coincides with the calculated straight line, so that the displacement of the tip corresponds to the force applied by the specific user, against the drawing surface;

b) calculating in real-time, the coordinates of the characteristic point while writing/drawing on the drawing surface; and

c) characterizing the specific user by collecting information related to the force applied by the specific user and/or the angle that is formed between the utensil and the drawing surface, while the specific user is writing/drawing.

Further characterization is carried out by collecting information related to the kinematic attributes of the utensil while the specific user is

writing/drawing. The surface further may comprise a calibration point for improving the accuracy of the graphical representation, the coordinates of which are known.

At least one of the aligned transmission points can also be a virtual point represented by at least two transmission points which are not aligned. The spatial coordinates of the virtual point are calculated by receiving signals transmitted from the at least two transmission points by the set of receivers, and processing the signal.

The invention is also directed to an apparatus for determining a spatial and/or planar position of a point, which comprises two or more transmitters essentially positioned along a straight line passing through the point, the position of which it is desired to determine, the point defining a tip. The system further receivers to receive signals transmitted by the transmitters, and computation apparatus to calculate therefrom the position of the tip.

The invention is also directed to a system for acquiring a graphical representation of one or more intersection points between a straight line and a surface having a known location and orientation, comprising:

a) two or more aligned transmission points being in any desired spatial orientation, each transmission point being separated from its neighboring point(s) by a first fixed distance lying substantially along the straight line, the straight line passing through the transmission points;

b) a set of receivers for receiving a signal transmitted from the at least two transmission points;

c) means for processing the signal and for determining the spatial coordinates of at least two transmission points; and

d) means for determining at least one characteristic point being co-linear with the transmission points, and separated from at least

one transmission point by a second fixed distance;

e) means for calculating the spatial coordinates of the characteristic point using the spatial coordinates of the at least two transmission points and the second fixed distance;

f) means for determining and/or calculating the spatial representation of the surface;

g) means for calculating the spatial coordinates of the intersect point; and

h) means for displaying a graphical representation of the surface, a first graphical representation indicating coincidence between the intersect point and the characteristic point, and a second and different graphical representation indicating lack of coincidence.

Brief Description of the Drawings

The above and other characteristics and advantages of the invention will be better understood through the following illustrative and non-limitative detailed description of preferred embodiments thereof, with reference to the appended drawings, wherein:

- Figs. 1A to 1D schematically illustrate a system for digitizing writing and drawing, according to a preferred embodiment of the invention;
- Figs. 1E to 1J schematically illustrate the transformation of data provided by the writing utensil being in interaction with a mobile writing surface, according to a preferred embodiment of the invention;
- Fig. 1K schematically illustrates a mobile writing surface having three transmission points, according to a preferred embodiment of the invention;
- Fig. 1L is a flow-chart of the discrimination operation between writing and pointing modes of the writing utensil, according to a preferred embodiment of the invention;
- Fig. 2 schematically illustrates the structure of the writing utensil of Fig. 1A, according to a preferred embodiment of the invention;

- Fig. 3 is a block diagram of a system for digitizing writing and drawing, according to a preferred embodiment of the invention;
- Figs. 4A to 4C schematically illustrate the calculation of the 3-D coordinates of the tip of the writing utensil according to a preferred embodiment of the invention;
- Fig. 5 schematically illustrates data inputting provided by the writing utensil from different tilt angles while keeping the tip at the same point, according to a preferred embodiment of the invention;
- Figs. 6A to 6C schematically illustrate the determination of the orientation of the writing utensil, according to a preferred embodiment of the invention;
- Fig. 7 schematically illustrates a portable system for digitizing writing and drawing, according to a preferred embodiment of the invention;
- Fig. 8A schematically illustrates the structure of a pressure-sensitive writing utensil, according to a preferred embodiment of the invention;
- Fig. 8B schematically illustrates the two states of a pressure-sensitive writing utensil, according to a preferred embodiment of the invention;
- Fig. 9 schematically illustrates a facsimile/E-mail system utilizing a system for digitizing writing and drawing, according to a preferred embodiment of the invention;
- Figs. 10A to 10C schematically illustrate the structure of an input device used as a pointing instrument from different aspects, according to a preferred embodiment of the invention;
- Figs. 11A to 11D schematically illustrate the structure and the operation of an input system for pointing on a surface, according to a preferred embodiment of the invention;
- Fig. 12 schematically illustrates the implementation of a writing utensil having erasing capability, which employs a conventional pen or pencil, according to a preferred embodiment of the invention;
- Figs. 13A and 13B schematically illustrate the implementation of a writing utensil having erasing capability, which employs a conventional

pen or pencil, according to another preferred embodiment of the invention;

- Fig. 14A schematically illustrates the writing/pointing mode of the writing utensil of Fig. 2, according to a preferred embodiment of the invention;
- Fig. 14B schematically illustrates the erasing/pointing mode of the writing utensil of Fig. 2, according to a preferred embodiment of the invention; and
- Fig. 14C schematically illustrates operation in the pointing mode of the writing utensil of Fig. 2 using both tips, according to a preferred embodiment of the invention.

Detailed Description of Preferred Embodiments

Figs. 1A to 1D schematically illustrate a system for digitizing writing and drawing, according to a preferred embodiment of the invention. The system 1000 comprises an elongated writing utensil 10 to which at least two transmitters 12 are attached. The two transmitters 12 are located along the central line (axis) of the elongated utensil 10 and are essentially aligned with the writing tip of the utensil 10. A position determining system 14 which receives transmitted signals from the transmitters 12 and determines the absolute positions of the transmitters 12, and a data processor 16, such as a computer (as shown, or a Palm cellular-phone with processing capability) or an integrated circuit chip, for processing the position information.

The position determining system 14 typically comprises at least three receivers 18 and a signal processor which converts the time of arrival of signals received from the transmitters 12 into three-dimensional position coordinates (X1,Y1,Z1) and (X2,Y2,Z2) of the two transmitters 12. The processor 16 is connected to the computer 16 by a cable through which the position coordinates are transferred. Alternatively, the collected data can be

transmitted using wireless transmission, such as Radio-Frequency (RF) or Infra-Red (IR) data carrying signals. The processor 16 can be implemented in several forms, such as a printed circuit board in the computer, integrated into a cellular phone, etc.

Looking now at Fig. 1B, the three receivers 18 are located on a structure formed of a housing 15 and two connecting lines 17 and 19 which intersect at a right angle. Two receivers, labeled 18a and 18b, are located at the ends of the connecting lines 17 and 19, respectively. The third receiver, labeled 18c, is located on the housing 15 at a position which is the intersection of the connecting lines 17 and 19. A calibration receiver 18s, described in more detail hereinbelow, is also located on the connecting line 17. A suitable type of a position determining system 14 comprising transmitters 12, receivers 18 and a signal processor 20 is the VS-110PRO or the VS100 system, both manufactured by VSCOPE of Israel. Another exemplary system which employs RF signals is the micro-power impulse radar system (time of flight version), developed by Lorens Livermo National Laboratories, USA.

According to a preferred embodiment of the invention, a user writes on a writing medium, such as a piece of paper 22 attached to a writing surface 23, each transmitter 12 continuously transmits signals. The computer (or another suitable data processor) 16 transforms the transmitter coordinates into position coordinates for a writing tip 24 of writing utensil 10; the collection of position coordinates forms the user's "drawing" 26, shown in Fig. 1A. Furthermore, since the writing utensil 10 writes onto a writing medium 22, the user has a "hardcopy" of the drawing 26. For example, if the user wants to store a digital version of his signature, he just signs his signature with the writing utensil 10 on the writing medium 22, as he normally does. While he writes, the system 14 calculates the positions of the writing tip 24, as well as the tilt of the utensil 10 and its kinematic parameters and stores them as the user's signature. Thus, in order to

digitize his signature, or any other graphical work, the user just writes on the paper 22. He does not have to view a display of a computer in order to produce his digital signature, as is true of prior art systems. The present invention is thus a writing utensil with an ability to digitally store written graphics. The writing surface 23 may further comprise two (or more) transmitters 18d and 18e, located at the extreme points L and R of the writing surface 23, respectively, as shown in Fig. 1B. This enables to change the position and/or the orientation of the writing surface 23 while drawing. For example, the user can start drawing when the writing surface 23 is placed on a table, and then concurrently walk in the room and continue drawing. The system 14 receives the signals transmitted from transmitters 18d and 18e, as well as from transmitters of the utensil 10, and continuously calculates the relative movement between the utensil 10 and the writing surface 23, while drawing.

Fig. 1C shows a structure, in which the housing 15 which contains the array of receivers 18a to 18s is fixed to the writing surface 23 (in this example, the receivers18a to 18s are RF receivers, and the receiver 18s is used for the synchronization required to calculate the timing of the emitted RF signals. If ultrasonic transmission is employed, synchronization can be carried out using a LED which emits IR signals). Using this structure eliminates the need to transmit from points L and R on the writing surface 23. The array of receivers 18a to 18s can be also fixed to the display of the computer 16, as shown in Fig. 1D. In that case, the housing 15 may be implemented as a Printed Circuit Board (PCB) in the computer.

According to a preferred embodiment of the invention, the system only stores the position coordinates of the trace 26 drawn on the paper. Whenever the user raises the writing utensil 10 from the writing surface 23, the system ceases storing position coordinates. It determines the raising of the writing utensil 10 by knowing the three-dimensional location of the

writing tip 24 and the spatial location and the orientation of the plane of the writing surface 23 (in this case, both transmitters 12a and 12b are active). Alternatively, only one transmitter can be activated when there is no contact between the writing tip 24 and the surface 23. When the user starts drawing, the applied pressure operates also the second transmitter, which indicates that there is contact and drives the system 14 to calculate the tip location accordingly. The transmitters 12 and receivers 18 can communicate in any suitable manner, such as using ultrasonic, supersonic, light or RF data-carrying signals of any suitable wavelength.

In the event when the writing surface 23 is static (fixed in location) and forms a plane which is parallel to the vertical or to the horizontal plane of the set of receivers18a to 18s, no transmitters are required on the writing surface 23. Alternatively, two reference points can be determined on the writing surface 23, which are sufficient to map (by calculations based on the known location of these two reference points) any drawn point to the display screen, or any point on writing surface 23, to which the tip of the writing utensil 10 is directed, whenever there is no contact between the tip 24 and the writing surface 23 (i.e., during pointing mode). These points are also used to determine the actual limits of the writing surface 23, as well as its orientation relative to the array of receivers.

Figs. 1E to 1J schematically illustrate the transformation of data provided by the writing utensil being in interaction with a mobile writing surface, according to a preferred embodiment of the invention. The writing surface 23 comprises two transmission points, L and R, which are received by the same set of receivers 18a to 18s (which receive transmission from the writing utensil). The transmitters located at points L and R provide data related to the movement of the writing surface 23, to the set of receivers. This data is further processed, and provides an indication related to any movement (relative to the set of receivers) of the writing surface 23. This

enables the user to move the writing surface 23 to any point before or while drawing. For example, the user can start drawing while sitting near a table, and then move the writing surface on the table while drawing. In the event when the writing surface 23 coincides, or is parallel with the X-Y plane of the set of receivers 18a to 18s (as shown in Fig. 1A) the mapping transformation of a point P in the X,Y,Z spatial coordinate system, into a digitized trace while calculating the orientation of the writing surface 23 relatively to the X,Y,Z spatial coordinate system is carried out by calculating the angle α between the vectors V_{LR} and V_P in Fig. 1E, as follows:

$$\cos\alpha = \frac{(X_P - X_L)\cdot(X_R - X_L) + (Y_P - Y_L)\cdot(Y_R - Y_L)}{|V_P|\cdot|V_{LR}|} \quad \text{[Eq. 1]}$$

wherein

$$|V_P| = \sqrt{(X_P - X_L)^2 + (Y_P - Y_L)^2} \quad \text{[Eq. 2]}$$

$$|V_{LR}| = \sqrt{(X_R - X_L)^2 + (Y_R - Y_L)^2} \quad \text{[Eq. 3]}$$

Mapping to a digitized trace on the display screen is carried out in this example from point L_S to point P_S. The coordinates (X_S, Y_S) of the point P_S are calculated using the following sensitivity factor K_P :

$$K_P = \frac{|V_S|}{|V_{LR}|} \quad \text{[Eq. 4]}$$

$$X_s = K_P \cdot |V_P| \cdot \cos\alpha \quad \text{[Eq. 5]}$$

and

$$Y_s = K_P \cdot |V_P| \cdot \sin\alpha \quad \text{[Eq. 6]}$$

wherein V_S is the mapping of the vector V_{LR} to the display screen. V_S represents the length of the display screen, and can be measured by placing

the tip in the two extremes of the display, or may be hardware determined. The factor K_P represents the sensitivity of the digitizing system. $K_P = 1$ is an indication that the displacement of the writing utensil 10 on the writing surface 23 is transformed into an identical displacement of the reconstructed tip location on the display screen. The digitizing system is less sensitive for $K_P < 1$ (i.e., the displacement of the writing utensil 10 on the writing surface 23 is transformed into a smaller displacement of the reconstructed tip location on the display screen). Similarly, the digitizing system is more sensitive for $K_P > 1$ (i.e., the displacement of the writing utensil 10 on the writing surface 23 is transformed into a greater displacement of the reconstructed tip location on the display screen).

A situation in which the writing surface 23 does not coincide with the plane defined by the set of receivers18a to 18s is shown in Fig. 1F. While the writing utensil 10 is operated in a drawing mode, the point P represents the point at which the tip 24 is in contact with the writing surface 23, and is defined by calculations of the coordinates of the tip 24. In this case, the vector V_P is calculated using the (known) coordinates of point P and the transmission point L. The vector V_{LR} is calculated using the (known) coordinates of the transmission points L and R. The angle α between the vectors and is calculated as follows:

$$\cos\alpha = \frac{(X_P - X_L)\cdot(X_R - X_L) + (Y_P - Y_L)\cdot(Y_R - Y_L) + (Y_P - Y_L)\cdot(Y_R - Y_L) + (Z_P - Z_L)\cdot(Z_R - Z_L)}{|V_P|\cdot|V_{LR}|} \quad \text{[Eq. 7]}$$

wherein

$$|V_P| = \sqrt{(X_P - X_L)^2 + (Y_P - Y_L)^2 + (Z_P - Z_L)^2} \quad \text{[Eq. 8]}$$

$$|V_{LR}| = \sqrt{(X_R - X_L)^2 + (Y_R - Y_L)^2 + (Z_R - Z_L)^2} \quad \text{[Eq. 9]}$$

The point P is mapped into a corresponding point on the display screen after the length $|V_P|$ is obtained. Therefore, the user can draw a trace on a writing surface 23 which coincides with any plane and comprises two transmission points L and R, even when the writing surface 23 is moving in the 3-D space.

When the tip 24 of the writing utensil 10 is not in contact with the writing surface 23, the point P represents a (known) transmission point of the writing utensil, which is closer to the writing surface 23 (i.e., point P is not on the writing surface 23 and the writing utensil functions as a pointer), the vector V_P that is calculated using the coordinates of point P does not coincide with the plane of writing surface 23. The length of the vector V_P, as well as the angle α between the vectors V_{P1} to V_{Pn} and V_{RL} vary (reduced) while moving the writing utensil 10 toward, and perpendicular to, the writing surface 23. Therefore, the location of the transformed point on the display screen varies, as shown in Figs. 1F to 1H. According to a preferred embodiment of the invention, if the writing surface 23 is stationary with respect to the set of receivers, a calibration point P is obtained on the writing surface 23 by attaching the tip 24 to the writing surface 23 at least once. The plane of the writing surface 23 can be defined by multiplying the vectors V_{RL} and V_{LC} (which is the vector defined between the transmission point L and the calibration point C). Therefore, the transformation of any point on the writing surface 23, on which the writing utensil 10 points (while operating as a pointer) can be either obtained along a line which passes through the known transmission points, and is perpendicular to the plane being horizontal to the plane that is defined by the set of receivers, or alternatively, to the writing surface 23, as shown in Fig. 1I. If the two transmitters 12a and 12b are continuously operated at points P_1 and P_2,, when the utensil is operated as a pointer, respectively, along the central axis of the writing utensil, the location of the "pointer" on the display screen

can be obtained by calculating equation of the line connecting between points P_1 and P_2, calculating the equation of plane defined by the writing surface 23, and finally calculating their intersection point, as shown in Fig. 1J.

Fig. 1K schematically illustrates a mobile writing surface having three transmission points, according to a preferred embodiment of the invention. The calculations of the relative position between the writing utensil 10 and the writing surface 23 is similar to those of a mobile writing surface having two transmission points (Fig. 1E), but for 3-D representation between the vectors V_P and V_{RL}. Hence, the point $P(X_P, Y_P, Z_P)$ on the writing surface 23 is mapped into point $P_S(X_S, Y_S)$ on the plane of the display screen as follows:

$$\cos\alpha = \frac{(X_P - X_L)\cdot(X_R - X_L) + (Y_P - Y_L)\cdot(Y_R - Y_L) + (Y_P - Y_L)\cdot(Y_R - Y_L) + (Z_P - Z_L)\cdot(Z_R - Z_L)}{|V_P|\cdot|V_{LR}|}$$

wherein

$$|V_P| = \sqrt{(X_P - X_L)^2 + (Y_P - Y_L)^2 + (Z_P - Z_L)^2} \qquad \text{[Eq. 10]}$$

$$|V_{LR}| = \sqrt{(X_R - X_L)^2 + (Y_R - Y_L)^2 + (Z_R - Z_L)^2} \qquad \text{[Eq. 11]}$$

$$K_P = \frac{|V_S|}{|V_{LR}|} \qquad \text{[Eq. 12]}$$

$$X_s = K_P \cdot |V_P| \cdot \cos\alpha \qquad \text{[Eq. 13]}$$

and

$$Y_s = K_P \cdot |V_P| \cdot \sin\alpha \qquad \text{[Eq. 14]}$$

Fig. 1L is a flow-chart of the discrimination operation between writing and pointing modes of a writing utensil which has no switches, according to a preferred embodiment of the invention. Such utensil may be for example, a real pencil on which three transmitters are located. In order to save power, at the first step 100k the system checks if there is a signal which is received

from the transmitters. If no, at the next step 100l the time lapses with no signal from the transmitters is accumulated. At the next step 100m, the system checks if the accumulated time exceeds a predetermined limit. If not yet, the system continues to expect for transmission. If yes, at the final step the power supply to the system is switched off.

If a transmitted signal is received, at the next step 100a, the 3-D coordinates of the transmission points along the writing utensil 10 are obtained. At the next step 100b, the location of the writing tip 24 is calculated using these the 3-D coordinates. At the next step 100c the digitizing system checks if the tip 24 is above (confined within the limits of the "box" defined by virtually moving the writing surface 23 up, along the Z axis) the writing surface 23. Of course, the user can draw a trace and/or point on both sides of the writing surface 23 (the array of receivers detects the orientation of the writing utensil 10). If no (i.e., the writing utensil is relatively far away from the writing surface 23), at the next step 100d no pointer is displayed on the display screen. If yes, at the next step 100e the digitizing system checks if the calculated coordinates of the tip 24 coincides with the writing surface 23 (i.e., the tip 24 "touches" the writing surface). If no, at the next step 100f a pointer is displayed on the display screen. If yes, at the next step 100g the digitizing system checks if the writing utensil 10 is inclined relatively to the writing surface 23 in an angle which is smaller than a predetermined "normal" writing angle. If the angle is larger, at the next step 100h a digitized trace is displayed on the display screen. If the angle is smaller, at the next step 100i the writing utensil 10 operates as a pointing device and a corresponding pointer is displayed on the display screen. At the next step 100j, the digitizing system seeks a single or a double emission from the transmitters of the writing utensil, which simulates a mouse "clicking" operations.

According to a preferred embodiment of the invention, the digitizing system

is used to reconstruct and/or to stores the position coordinates of a 3-D drawn trace. In some applications, the drawing surface is not flat (i.e., a convex or concave surface, or a combination thereof), and therefore the writing tip 24 moves in three dimensions while drawing (the same happens while erasing). Since the 3-D coordinates of the writing tip 24 are continuously calculated, by aggregating and storing the collected 3-D data, the digitizing system can simulate the shape of the writing surface, and display a 3-D reconstructed trace on the display screen. The accuracy of the 3-D reconstructed trace is continuously improved as further 3-D data is collected while drawing.

Fig. 2 schematically illustrates the structure of the writing utensil of Fig. 1A, according to a preferred embodiment of the invention. The writing utensil 10 comprises a body 30 generally having the shape of a typical writing utensil, at least two transmitters 12 aligned along the central axis of the utensil 10 and coincide with its tip 24, circuitry 32 for powering and controlling the transmitters 12, at least one optional indicator button (one is shown) 34 and a removable writing head 36. If desired, the writing utensil 10 can also include an eraser 38 for erasing some or all of the drawing 26. The optional indicator button 34 controls the transmission from a single transmitter 12. Typically, when a button 34 is pressed, transmission is allowed from the selected transmitter. The button 34 may be connected in parallel to the pressure-sensitive switch, so as to enable activation of both transmitters even when there is no contact between the tip and the writing surface (e.g., at pointing mode). Otherwise, transmission is disabled from that transmitter. According to a preferred embodiment of the invention, the writing head 36 comprises a graphite writing tip, which functions as a pencil, or an ink writing tip, which functions as a pen. The writing head 36 is typically connected to the body 30 by using any suitable connection, such as screws or snap connectors. When the writing utensil is in a writing/drawing position (i.e., when the writing tip 24 points toward the

writing surface 23), a pressure-sensitive switch is operated at the moment when the tip is in contact with the writing surface 23. The mechanical pressure provides an indication that the user wishes to draw a trace, and causes both transmissions 12 to transmit and provide the data required to determine the location of the writing tip 24. Whenever the user wishes to terminate the drawing state, he removes the tip from the writing surface 23 and the transmission from at least one transmitter 12 is stopped. Normally, in the pointing mode the farther (from the writing surface) transmitter is disactivated, and the utensil 10 is operates as a pointing instrument while only the closer transmitter is active.

When the user wishes to operate the utensil 10 as an eraser (i.e., to digitize erasing operation and to implement it on the digitized drawn trace), he reverses the orientation of the utensil 10 to point toward the writing surface 23, this time with the eraser (i.e., the normally farther transmitter is now closer to the writing surface 23), and operates a mode selector 43 (which is actually another switch, implemented by using the grip of the utensil) that switches the pointing direction. The mode selector terminates transmission from the transmitter located near the writing tip, and initiates transmission from the transmitter located near the erasing tip. When the user applies pressure on the erasing tip (against the writing surface), the other transmitter which is closer to the writing/drawing tip is also activated, and the location of the erasing tip on the writing surface is calculated according to transmission from both transmitters. The radius of the erased area is determined by the angle between the writing utensil and the drawing surface (which can also be calculated when both transmitters are activated). The maximal erased area is obtained when the angle is a right angle. The writing utensil 10 further comprises a main power switch 41, which is used to connect or to disconnect the power supply to each transmitter 12, whenever the utensil is not in use.

Fig. 14A schematically illustrates the writing/pointing mode of the writing utensil of Fig. 2, according to a preferred embodiment of the invention. As long as the writing tip points toward the writing surface 23, only the normally lower (the closer) transmitter transmits, and the utensil 10 functions as a 3-D cursor, which approximately simulates the location of the writing tip 24 above the writing surface 23. A closer location of the writing tip 24 to the writing surface 23 results in more accurate simulation of the actual tip location. When the user starts to draw the trace, he brings the writing tip 24 into contact with the writing surface 23 and applies a continuous pressure, which causes both transmitters to transmit simultaneously. As a result, the drawn trace is accurately digitized and displayed on screen.

Fig. 14B schematically illustrates the erasing/pointing mode of the writing utensil of Fig. 2, according to a preferred embodiment of the invention. As long as the eraser 38 points toward the writing surface 23, only the normally upper (the farther) transmitter transmits, and the utensil 10 functions as a 3-D cursor, which approximately simulates the location of the eraser 38 above the writing surface 23. Switching the transmission to the transmitter which is closer to the erasing tip can be carried out manually by the mode selector 43, or automatically, by a switching unit that is responsive to the gravitation force. A closer location of the writing eraser 38 to the writing surface 23 results in more accurate simulation of the actual eraser location. When the user starts to erase the drawn trace, he brings the eraser 38 into contact with the writing surface 23 and applies a continuous pressure, which causes both transmitters to transmit simultaneously. As a result, the drawn trace is accurately digitized and displayed on screen. The mode selector 43 switches the location (upper or lower) of the currently operating transmitter, in both writing or erasing modes. Normally, when the mode selector 43 is depressed, the transmitter which is closer to the erasing tip is activated, and when released, transmission is switched to the

transmitter which is closer to the writing tip.

According to a preferred embodiment of the invention, the writing utensil 10 is operated as a selection and/or an executing device, which simulated the operation of a widely used "mouse". The user can bring the writing tip 24 to be in contact with the writing surface 23, and point with the tip on a drawn object. The user can then "select" an object by depressing the writing utensil 10 once against the writing surface 23, followed by a release (i.e., "clicking" on the pointed object). A resulting single pulse is received by the set of receivers from the farther transmitter, and the selected object can be manipulated by the writing utensil 10. For example, the "selected" object can be "dragged" on the display screen by the user. In addition, an object may be associated with execution program, and the user can operate the program by depressing the writing utensil 10 against the writing surface 23 twice, followed by a release (i.e., "double clicking" on the pointed object), as shown in Fig. 14A above. In both conditions, the writing utensil is controlled to disable writing or drawing. Similar "clicking" and or "double clicking" operations can be obtained when the eraser 38 is closer to the writing surface 23 and when the mode selector 43 is depressed, as shown in Fig. 14A above. Whenever desired, a single transmitter can be selected and activated by switching the state of a selection switch, which is located near the erasing tip of the writing utensil 10. This enables the user to operate the writing utensil 10 as a pointing device at each orientation of the writing tip or the erasing tip, as shown in Fig. 14C.

Fig. 3 is a block diagram of a system for digitizing writing and drawing, according to a preferred embodiment of the invention. Each of the receivers 18a to 18s receives the output of transmitters, labeled 12a and 12b, and provides the output to the signal processor 20 which determines therefrom the three-dimensional location coordinates (Xa,Ya,Za) and (Xb,Yb,Zb) of transmitters 12a and 12b, respectively. The coordinate values are provided

to the data processor 16 which comprises a drawing parameter determiner 40 for determining at least the location status of the tip 24, calculation unit 410 which calculates the location of the tip, and an optional filter 42, such as a low pass filter, for filtering out undesired movement of the writing tip 24 (considered as "noise"). The output of the data processor 16 can be provided to any suitable device, such as to a display screen 44 and/or a storage device 46, and/or a modem for further processing. Each receiver from the group 18a to 18s is characterized with a pair of distances, <l*aa*, l*ab*> to <l*ca*, l*cb*>, respectively, from each transmitter.

Figs. 4A to 4C schematically illustrate the calculation of the 3-D coordinates of the tip of the writing utensil according to a preferred embodiment of the invention. The drawing parameter determiner 40 checks which transmitter is currently active and its current position, and calculates the coordinates (Xc,Yc,Zc) of tip 24 from the coordinate values (Xa,Ya,Za) and (Xb,Yb,Zb) which are determined by the set of receivers 18a to 18c. The distance between the two transmitters 12a and 12b is Lab and the distance between transmitter 12b and the tip 24 (point c) is L*bc*. The transmitters 12a and 12b and the tip 24 are collinear, and normally coincide with the central axis of the utensil 10. The drawing parameter determiner 40 first determines the tilt angle α which is formed between the central axis of the writing utensil 10 and the X-Z plane. It is determined by Equation 1 hereinbelow and is illustrated in Fig. 4B:

$$\alpha = \mathrm{Sin}^{-1}[(Za - Zb)/L_{ab}] \qquad \text{[Eq. 15]}$$

Assuming that in this example the utensil 10 is always above the writing surface 23, the calculation unit 410 calculates (using the tilt angle α) the height coordinate Zc of the tip 24, the length $L\beta$ of the projection of the distance Lab on the X-Y plane and the length L0 of the projection of the distance L*bc* on the X-Y plane as follows:

$$Zc = Zb - L_{bc}\sin(\alpha) \qquad \text{[Eq. 16]}$$

$$L_{\beta} = L_{ab}\cos(\alpha) \qquad \text{[Eq. 17]}$$

$$L_0 = L_{bc} \cdot \mathrm{Cos}(\alpha) \qquad \text{[Eq. 18]}$$

The calculation unit 410 calculates (using the calculated angle β and the projection L_β) the coordinates Xc and Yc of the tip 24, in the X-Y plane as follows and as shown in Fig. 4C:

$$\beta = \mathrm{Cos}^{-1}[(X_a - X_b)/L_\beta] \qquad \text{[Eq. 19]}$$

The value of β is also a function of the coordinate quadrant in which the coordinates are located. Thus, the values of Ya and Yb are needed to determine the value of β. Finally, the Xc and Yc coordinates of the tip 24 are calculated using the angle β as follows:

$$X_c = X_b - L_0\mathrm{Cos}(\beta) \qquad \text{[Eq. 20]}$$

$$Y_c = Y_b - L_0\mathrm{Sin}(\beta) \qquad \text{[Eq. 21]}$$

Both transmitters 12a and 12b determine a straight line and, any point along that line can be calculated. Thus, using calculations similar to those detailed hereinabove, the drawing parameter determiner 40 can also determine the location (X_E,Y_E,Z_E) of eraser 38 which is located at a distance L_{aE} from transmitter 12a. Whenever the drawing parameter determiner 40 indicates that the eraser 38 is touching the writing surface 23 (i.e. when transmitter 12a is closer to the writing surface than transmitter 12b or when eraser 38 activates a switch (not shown)), the calculated data points are stored in a different array. Whenever desired, they are used to remove

from screen, those stored data-points which are near the locations of the eraser 38. The coordinates of the eraser 38 can also be filtered by the filter 42, so as to remove noise effects.

The locations of the writing tip 24 and eraser 38 and the angles α and β, which provide orientation information, can be utilized as the basis for further applications. For example, the writing utensil 10 can be used to as a data input device for drawings, handwritten manuscripts and signatures. It can be used to fill in forms, if handwriting is required. It can also form part of a facsimile system, where the digitized trace can be processed and transmitted over a telephone line as a compressed image (normally used to transfer fax messages) to a receiving fax machine. The processing and transmission can be carried out in real-time, so as to enable a user at the receiving point to obtain the drawn trace on his screen display. Of course, the digitized trace can be delivered to remote receiving points using other E-mail channels and/or wireless communication devices, such as cellular phones.

According to a preferred embodiment of the invention, the system 1000 can further be used as a graphological tool, to identify the user by his handwriting and for character recognition. For this purpose, when a user signs his signature, data related to both the signature itself (the locations of the writing tip) and to the movement of his hand (the tilt of the writing utensil 10 while writing) is collected. Additional parameters, such as the kinematic properties of the hand movement can also be used to characterize the user. For example, the linear velocity of the writing tip, its direction relative to the trace, angular velocity, linear and/or angular acceleration, and dynamic parameters which can be analyzed and used to characterized the user. The (combined) collected information is then utilized to analyze the produced signature, either for graphological analysis and/or to identify the signer. This combination also provides sufficient information to

recognize characters since the hand motions required to produce a letter (or any other character/symbol) can be often defined in the same level of accuracy as the characters themselves. Both recognition methods can be used together and significantly reduce handwriting recognition errors. This technique is described in more details, for example in the article "Trajectory Formation and Handwriting: A Computational Model" by Morasso and Ivaldi, Biological Cvbernetics, Springer-Verlag, 1982, pp. 131 - 142, which is incorporated herein by reference.

According to another preferred embodiment of the invention, the digitizing accuracy can be further improved by calculating, in real-time, the actual (current) length l_{bc} of the writing utensil 10. Such calculation is required in particular when the physical length l_{bc} is slightly changed while the writing utensil 10 is in use (e.g., when the writing tip is a pencil, which is slightly shortened during relatively long use, or when the pencil is sharpened). Looking again at Figs. 4A and 4B above, at a given time t_0, the coordinates of the points A(Xa,Ya,Za), B(Xb,Yb,Zb) along the writing utensil 10 are known (the location of the transmitters 12a and 12b, respectively), the actual (current) length l_{bc} can be determined by calculating the coordinates of point C(Xc,Yc,Zc).

Using the geometric properties between the triangles of Fig. 4C, the following relations are determined:

$$\frac{Xa-Xc}{Xb-Xc}=\frac{Ya-Yc}{Yb-Yc}=\frac{Za-Zc}{Zb-Zc} \qquad \text{[Eq. 22]}$$

By isolating only the X and Y components, the relationship is reduced to:

$$\frac{Xa-Xc}{Xb-Xc}=\frac{Ya-Yc}{Yb-Yc} \qquad \text{[Eq. 23]}$$

therefore:

$$(Xa\text{-}Xc)\cdot(Yb\text{-}Yc)=(Xb\text{-}Xc)\cdot(Ya\text{-}Yc) \qquad \text{[Eq. 24]}$$

After rearranging, the following equation is obtained:

$$(Ya-Yb)Xc+(Xb-Xa)Yc=XbYa-XaYb \qquad \text{[Eq. 25]}$$

The same calculation can be done at a different moment t_1, this time with a different tilt angle, while the tip of writing utensil remains at point C (i.e., without moving the tip). As a result, the values *Xa*, *Ya*, *Xb* and *Yb* are changed to *X'a*, *Y'a*, *X'b* and *Y'b*, respectively, and a similar equation is obtained for the new tilt angle:

$$(Y'a-Y'b)Xc+(X'b-X'a)Yc=X'bY'a-X'aY'b \qquad \text{[Eq. 26]}$$

Therefore, the desired values ***Xc*** and ***Yc*** are obtained from the set of equations 7d and 7e. The last value ***Zc*** is calculated from the following relationship:

$$\frac{Ya-Yc}{Yb-Yc}=\frac{Za-Zc}{Zb-Zc} \qquad \text{[Eq. 27]}$$

Finally, the desired length l_{bc}, which is the distance between points B and C is given by:

$$l_{bc}=\sqrt{(Xc-Xb)^2+(Yc-Yb)^2+(Zc-Zb)^2} \qquad \text{[Eq. 28]}$$

By repeating this calculation several times, the measured length l_{bc} can be averaged, and the system accuracy can be estimated using statistical analysis.

Fig. 5 schematically illustrates data inputting from the writing utensil from different tilt angles, according to a preferred embodiment of the invention. The same 3-D coordinates of the tip 24 are obtained from any tilt angle, since the writing tip 24 continues to direct toward the same point on the

writing surface 23. Four input devices (writing utensils), labeled 10a - 10d, each having a different tilt angle α_i and direction β_i, wherein i=1,..,4 (the angles β_i are not shown). Although it may be easy to counterfeit the shape of a hand-written trace, such as a signature, the counterfeiter is not likely to hold and/or to move his hand while writing essentially in the same typical angles, velocities and acceleration while drawing the same trace as drawn by the original signer.

Figs. 6A to 6C schematically illustrate using a calibration process of the location of writing tip relative to the closest transmission point, according to a preferred embodiment of the invention. In this example, the writing utensil is a standard writing instrument 54 having three transmitters 12 attached thereto. Each transmitter 12 is attached to the writing instrument 54 via a clip 56. The transmitters 12 can be placed in any coplanar arrangement, at any desired locations, on the writing instrument 54. The three transmitters 12 define a plane and the orientation of the plane. The position of the writing tip 24 can be determined using conventional vectoric calculations.

Since the transmitters 12 can be located anywhere along the writing instrument 54, the location of the writing tip 24 is not immediately known, nor are the distances Lbc, Lab, Lae, and L3, where L3 is the distance between the second and third transmitter and the remaining distances are as described hereinabove. In order to determine these relationships, the calibration button (e.g., a wireless transmitter) 58, is utilized. During the calibration process when the writing tip 24 (of instrument 54) touches the calibration button 58, the position of each transmitter (from the three transmitters) is measured. The location of the calibration button 58 is also measured, and the distance from each transmitter to the calibration button 58 is calculated. While using the writing instrument, the location of the writing tip is obtained by calculating the vectorial product between two

adjacent vectors on this plane (each vector is defined by two transmission points, where one transmission point is common to the adjacent vectors). The location of the writing tip is then obtained by calculating the intersection point of the three distances that was measured in the calibration procedure, i.e., the three distances between the tip and each transmitter. Whenever the length of the writing instrument 54 changes, such as after sharpening of tip 24, or when the location of one or more transmitters 12 is changed, a new calibration is performed, so as to re-determine the distance of the writing drawing tip 24 from the transmitters 12a, 12b and 12d. The calibration button 58 may be a selected transmitter attached to the movable writing surface 23, as shown in Fig. 6A (where transmitter L is selected), or may be a point having known coordinates relative to the set of receivers, as shown in Fig. 6B, or out of the writing surface 23 on a transmitter, the coordinates of which are known, wherein calibration is obtained by using a transmitter with known location relative to the set of receivers, as shown in Fig. 6C.

Fig. 7 schematically illustrates a portable system for digitizing writing and drawing, according to a preferred embodiment of the invention. The portable system 70 comprises a writing utensil 10 and a housing 51 storing the position determining system and the data processor 16. In this embodiment, spokes 17 and 19 are replaced by telescopic spokes 53 and 55 extending out of the housing 51. As in the previous embodiments, telescopic spokes 53 and 55 have receivers 18a and 18b, respectively. The third receiver 18c is located on the housing 51 at a position, which is the intersection of the spokes 53 and 55. If desired, the calibration button 58 can be included, on a rigid spoke 57 (calibration is not required when conventional utensil is used, since its physical dimensions are fixed). Alternatively, the connection between the calibration button 58 and the housing 51 can be wireless. An optional display 59, such as a liquid crystal display (LCD) can also be included for monitoring the digitized trace on screen. The housing 51

typically encloses an integrated circuit chip (not shown) which implements the data processor 16 and the signal processor 20. The housing 51 can also enclose a storage unit (not shown), an optional modem, and a connection to a computer. Connection to remote processing and display units may also be provided by using a cellular phone. The digitized data, from which the drawn trace can be reproduced can be transmitted over a telephone line and/or a cellular phone communication channel via the optional modem to a remote workstation, on which the digitized data is displayed. Alternatively, or in addition, the digitized data can be directly (or after compression) transmitted to a remote fax machine which generates a print out of the digitized trace.

Fig. 8A schematically illustrates the structure of a pressure-sensitive writing utensil, according to a preferred embodiment of the invention. The writing utensil 59 typically comprises a movable writing head 60 having a writing tip 24 as in the previous embodiment and which can slide within a borehole 62 of the utensil's body 64. Within the borehole 62 there is a spring 66 which resists to the movement of the writing head 60 into the borehole 62, by applying a contrary mechanical force. The extent of the contraction of the spring 66 is determined, as described in detail hereinbelow, and is utilized by the drawing parameter determiner 40 to determine the pressure applied by the user while (drawing and) pressing the writing utensil 59. The writing head 60 and body 64 may further include contacts 68 for indicating when writing has commenced. When writing head 60 slides slightly into borehole 62, contact 68 closes an electric circuitry, thereby indicating that writing has commenced. The transmitter which is currently closer to the writing surface 23 is continuously activated and functions as a pointer on the surface. When the contact 68 is depressed, the farther transmitter is also activated and initiates the calculation process of the writing tip's coordinates. Contact 68 is maintain closed (i.e., electrically conductive) while writing head 60 moves further into borehole 62.

Fig. 8B schematically illustrates the two states of a pressure-sensitive writing utensil, according to a preferred embodiment of the invention. At the normal state, no pressure is applied (by the user) to the writing head 60, and the distance between the two transmitters 12a and 12b is L_0. When the user starts drawing or writing, pressure is applied, and the spring 66 is contracted. This causes a displacement of a distance *dz* in the location of the lower transmitter 12b, and therefore, the initial distance L_0 is shortened to $L_t = L_0\text{-}dz$. If the elastic constant K of the spring 66 is known, the applied (by the user) force F is given by:

$$F=K\cdot dz$$

Since the writing utensil 10 is normally forms a sharp or an obtuse angle with the writing plane 23, the applied force F comprises a tangential component F_t coinciding with X-Y plane, and a radial component F_r coinciding with the central axis. These components can be used to characterize a trace drawn by a particular user and to simulate the change of width of the drawn trace.

According to a preferred embodiment of the invention, the applied force can be sensed by employing a piezoelectric element, to which the force is transferred from the writing tip. The electric signal produced by the piezoelectric element (and corresponds to the applied pressure) is used to modulate the signal that is transmitted from one of the transmission points. The modulated signal is demodulated and the carried information is translated to another signal being indicative to the applied force.

Fig. 9 schematically illustrates a facsimile/E-mail system utilizing a system for digitizing writing and drawing, according to a preferred embodiment of the invention. The facsimile system 900 comprises an input system 80, a

computer 86, and a receiving system 84, three types of which, systems 84a - 84c, are illustrated in Fig. 9. The input system 80 is the system for digitizing writing described above. The receiving system 84a is a computer 90 being linked to a data network 95, the receiving system 84b is a computer 91 communicating with computer 86 via modems 94, and the receiving system 84c is a facsimile machine 93. In order to use the facsimile system, the user writes a facsimile message on a writing medium 22 (e.g., a paper, or any other suitable surface) which is digitized by the input system 80 as a series of different writing tip positions. Data related to the orientation of the writing utensil 10 can also be recorded. The digitized data is transmitted to the appropriate receiving system 84 via the appropriate communication equipment (the modems 94 or the data network 95). Receiving system 84 rasterizes the tip positions and provides the facsimile message to the user. In receiving system 84a, the facsimile message is displayed on a suitable monitor 99. The system 900 including the receiving system 84a can form part of an electronic mail (E-mail) system by which users can send handwritten messages to each other, including signature identification, such as described hereinabove, to identify the user. Typically, if signature identification is desired, the message also comprises the orientation and kinematic information for identification capability of the user.

Using system 84b, the drawn trace is printed out by a printer 92, while using system 84c, the drawn trace is produced by a facsimile system 93. In order to send the digitized drawn trace to system 84c, the message is first provided to a facsimile code translator which rasterizes the message and then converts it to a suitable facsimile code. Although this does not necessarily reduce the transmission time, the input system 80 eliminates the need for scanning (i.e. rasterizing) a handwritten message in order to send the message via facsimile.

Figs. 10A to 10C schematically illustrate the structure of an input device used as a pointing instrument from different aspects, according to a preferred embodiment of the invention. The input device 100 comprises an illumination device, such as a laser diode 102, producing a beam 104, for illuminating distal points to which the tip is directed. Additionally, the position of the pointer relative to the pointed surface which is calculated by the equation of the line passing through the transmitters is represented as a cursor on the screen display. The input device 100 also comprises control buttons, 106 and 108, simulating mouse buttons, and a transmission control button 109. The control button 109 is operated in combination with an electronic circuit (not shown), so as to generate a pointing beam 104, only when depressed. During this (pointing) period the transmitters 12a and 12b are continuously activated to allow the computation of the intersection point of the line passing through points 12a and 12b with the pointed surface and thereafter simulate the cursor on the display screen. A main switch 111 is used to enable/disable the operation of the input device 100. A depressed button can be identified for example, by modulating the RF pulse emitted from the transmitter.

Figs. 11A to 11D schematically illustrate the structure and the operation of an input system for pointing on a surface, according to a preferred embodiment of the invention. The pointing system first determines the location of the surface 110, using the method described hereinabove. The system is brought to a location 111, relatively close to the surface 110, and the input device 119 is placed in at least two different orientations. The measured positions are denoted by the points P1, P2 and P3, as shown in Fig. 11C. Since the transmitters 12a and 12b define a line and since two lines define a plane, the input device 119 can be used to calculate the plane equation of the surface 110. Two planes are shown, the right one with the input device 119 in two locations and the left one showing the vectors of the locations of the transmitters in the two locations. Calibration is carried out

by placing the input device 119 in two different orientations on the surface 110 and acquiring the position of each transmitter, 12a and 12b. The first position of each transmitter 12a and 12b is labeled as A and B, respectively, and the second position of each transmitter 12a and 12b is labeled as C and D, respectively. In order to obtain sufficient accuracy in the surface orientation calculation, the body (shown in Fig. 10B) of input device 119 typically has a flat surface (not shown), on which the input device 119 can be attached to surface 110. It is noted that each transmitter 12 is located a distance h above flat surface 75 of the pointing device 119. This is noted in the vectors of Fig. 11D, which give the coordinates of points A' - D' which are the locations of the transmitters 12 if they were on the surface 110.

Since the positions A', B' and C', define a plane, the equation of the plane of the surface 110 can be derived therefrom. First, vectors V1 and V2 (shown in Fig. 11D) are determined as follows:

$$\mathbf{V1} = A'B' = [(XA - XB), (YA - YB), (ZA - ZB)] = [x1,y1,z1] \qquad \textbf{[Eq. 29]}$$

$$\mathbf{V2} = A'C' = [(XA - XC), (YA - YC), (ZA - ZC)] = [x2,y2,z2] \qquad \textbf{[Eq. 30]}$$

The vector V3 which is normal to the surface 110, is determined by the cross-product of vectors **V1** and **V2**:

$$\mathbf{V3 = V1 \times V2}$$

$$\mathbf{V3} = [(y1*z2 - z1*y2),(x1*z2 - z1*x2),(x1*y2 - y1*x2)] = [x3,y3,z3] \qquad \textbf{[Eq. 31]}$$

The equation of the surface 110 is given by:

$$x3*X + y3*Y + z3*Z + R + h = 0 \qquad \textbf{[Eq. 32]}$$

where h is the distance between the plane of the transmitters and the plane

of surface 110 and the value of R is determined by replacing (X,Y,Z) in equation 32 with the coordinate value (X_A, Y_A, Z_A) of point A. The location (X0,Y0,Z0) of the illuminated point at any time is determined by finding the intersection of the vector or line defined by the current locations (X1,Y1,Z1) and (X2,Y2,Z2) of the transmitters 12a and 12b with the plane described in equation 32.

The vector V4 of the input device 119 is given by:

$$V4 = [(X1 - X2), (Y1 - Y2), (Z1 - Z2)] = [K,L,M] \qquad \text{[Eq. 33]}$$

Since any point on vector V4 represents a scalar distance Q from a known point on the vector, the coordinates of the illuminated point are a function of the coordinates of one of the transmitters 12:

$$\begin{aligned} X0 &= X2 + Q*K \\ Y0 &= Y2 + Q*L \\ Z0 &= Z2 + Q*M \end{aligned} \qquad \text{[Eq. 34]}$$

Since (X0,Y0,Z0) is a point on the surface 110, equation 34 can be substituted into equation 32, producing the equation:

$$x3*(X2 + Q*K) + y3*(Y2 + Q*K)+ z3*(Z2 + Q*K) + D = 0 \qquad \text{[Eq. 35]}$$

which is one equation with a single unknown variable, Q. After solving equation 35 for Q, equations 13 can be solved, providing the intersection of the vector V4 with the plane, which intersection point is usually the location of the illuminated point.

The position determining apparatus 14 and the input device 119 are then moved to a known location 112 at some distance from the surface 110, marked in Fig. 11A with solid lines. The relationship (distance and

orientation) between locations 111 and 112 are either known or measured and are provided to the data processor 16. Using this information, the data processor 16 determines a transformation between the two axis systems, so as to determine the equation of the plane of surface 110 in the frame of reference of the second location 112. The user points (the control button 109 may either be depressed or not depressed) with the input device 119 towards a point on surface 110. The point is lit up by beam 104 (generated by the light source 102). When the desired location or the object is illuminated, the user depresses transmission control buttons 106 or 108 at which point the signals from the transmitters 12a and 12b are transmitted and recorded. Therefore, the input device 119 can function as a mouse.

The position of the illuminated point is determined by the intersection of a vector V4, defined by the two transmitters 12a and 12b, and the plane of the surface 110. The calculations required to determine the position of the illuminated point are provided in Eq. 29 to 35 hereinabove. As long as the area from which the pointer is operated is within the receiving range the set of receivers 18a to 18s, there is no need to move the array of receivers. Otherwise, the array of receivers is moved closer to the area for the purpose of calibration and then the array of receivers is moved close to the user, and the user points toward the writing surface from a distant location.

Looking at Fig. 11B, the equation representing the writing surface is obtained by carrying out calculations which are based on points having known coordinated on that surface. Each pair of points on the surface represents a corresponding vector which coincides with the writing surface. The equation is obtained by performing a vectorial multiplication between adjacent vectors on the surface, as explained with reference to Fig. 11D hereinabove. The accuracy of the representation is increased by performing several vectorial multiplications. Accurate transformation can be obtained by knowing the values of the transforming vector 113, as well as the

orientation of the set of receivers in the new location, relative to the previous location, as shown in Fig. 11A.

If prior to computation there is no available information related to the dimensions of the display screen and/or its location, then during the calibration procedure the pointing device should be directed to the horizontal and to the vertical margins of the display screen (or of the display area). Therefore, if the location of the display screen and the set of receivers is fixed, a single calibration procedure is sufficient. The pointing capabilities can be further expanded to areas external to the displayed area by defining them as objects. Whenever the pointing device is directed to such object, a predetermined operation can be executed by carrying out a clicking operation on buttons in the pointing device. This for example, allows to point on one or more objects projected on a display area (e.g., a wall or a curtain), to select an object and execute an operation associated with the selected object in the computer (the display of which is projected) that can be located farther.

Fig. 12 schematically illustrates the implementation of a writing utensil having erasing capability, which employs a conventional pen or pencil, according to a preferred embodiment of the invention. The writing utensil 120 comprises a housing 121 and micro-switches 122 and 124 which are activated when either a writing element 126 or an eraser 128 are depressed, during writing or erasing, respectively. When one of micros-witches 122 or 124 is activated, it activates both transmitters 12a and 12b. When no writing or erasing operations are carried out, the transmitter 12a or 12b is activated as described hereinabove with reference to Figs. 20A to 20C. The writing utensil 120 also comprises mounting elements 130, 132 and 134 for holding the writing element 126 and the eraser 128 within housing 121 while allowing them to move slightly to activate the micro-switches 122 and 124. Element 130 holds the writing element 126 near its writing tip,

element 132 holds the writing element 126 near an end and element 134 holds the eraser 128. Each element 130, 132 and 134 is formed of a clamping element 136 held within a small space 138. The space 138 is slightly larger than the clamping element 136, thus allowing it to move slightly and to activate the relevant micro-switch, 122 or 124. The clamping element 136a may consist of a ring 140 and washer 142. The writing element 126 and eraser 128 also held by elements 132 onto which micro-switches 122 and 124 are attached.

Figs. 13A and 13B schematically illustrate the implementation of a writing utensil having erasing capability, which employs a conventional pen or pencil, according to another preferred embodiment of the invention. In this example, the writing utensil one transmission point 12a which is aligned with the longitudinal axis of the utensil 130, and two additional transmission points 12l and 12r, located at the same plane (which is also perpendicular to the longitudinal axis, as shown in Fig. 13A. The utensil 130 is inserted into a housing 131, which eliminates the option to align an additional transmission point with the longitudinal axis. In this case, a "virtual" transmission point b is simulated by the two transmitters 12l and 12r, and the location of each tip is calculated as described hereinabove for an actual transmission point by using the calculated coordinates of the "virtual" transmission point b. The calculation of each transmission point is shown in Fig. 13B. Assuming that the transmission points 12r and 12l are located symmetrically to the longitudinal axis, the coordinates (Xb,Yb,Zb) of the "virtual" transmission point b are calculated from the coordinates (Xr,Yr,Zr) and (Xl,Yl,Zl) of the transmission points r and l, respectively, as follows:

$Xb=0.5(Xr+Xl)$

$Yb=0.5(Yr+Yl)$

$Zb=0.5(Zr+Zl)$

The calibration procedure for obtaining the distance Lbc from the virtual point b to the end point c of the writing tip is described hereinabove with reference to Eqs. 22 to 28.

The above examples and description have of course been provided only for the purpose of illustration, and are not intended to limit the invention in any way. As will be appreciated by the skilled person, the invention can be carried out in a great variety of ways, employing more than one technique from those described above, all without exceeding the scope of the invention.

CLAIMS

1. A method for determining spatial and/or planar position of a point comprising positioning two or more transmitters substantially along a straight line passing through the point, the position of which it is desired to determine, and calculating said position using the position of said two or more transmitters, the distance between them and the distance between said point and one of the transmitters.

2. A method for acquiring a graphical representation of one or more intersection points between a straight line and a surface having a known location and orientation, comprising:

a) receiving transmissions from two or more aligned transmission points being in any desired spatial orientation, each transmission point being separated from its neighboring point(s) by a first fixed distance, said transmission points lying substantially along said straight line;

b) determining the spatial coordinates of at least two transmission points by receiving a signal transmitted from said at least two transmission points in a set of receivers, and processing said signal;

c) determining at least one characteristic point being co-linear with said transmission points, and separated from at least one transmission point by a second fixed distance;

d) calculating the spatial coordinates of said characteristic point using the spatial coordinates of said at least two transmission points and said second fixed distance;

e) determining and/or calculating the spatial representation of said surface;

f) whenever said straight line and said surface intersect, calculating the spatial coordinates of said intersect point; and

g) displaying, on a graphical representation of said surface, a first graphical representation indicating coincidence between said

intersect point and said characteristic point, and a second and different graphical representation indicating lack of coincidence.

3. A method according to claim 2, wherein each characteristic point represents the location of a tip of an elongated instrument, the longitudinal axis of which essentially coincides with the calculated straight line.

4. A method according to claim 3, wherein whenever there is coincidence between the intersect point and the characteristic point, the instrument is used as a utensil by exploiting the tip for writing/drawing on the surface, a trace being reproduced on a display and/or in a data storage means by the graphical representation according to the relative movement between said tip and said surface.

5. A method according to claim 3, wherein whenever there is coincidence between the intersect point and the characteristic point, the instrument is used as a utensil by exploiting the tip for erasing from the surface, a portion of a drawn trace which is reproduced on a display and/or in a data storage means by the graphical representation, by removing a corresponding portion from said graphical representation according to the relative movement between said tip and said surface.

6. A method according to claims 3 and 4, wherein whenever there is coincidence between the intersect point and the characteristic point, the instrument is used as a utensil by exploiting a combination of a writing/drawing tip at one end of said utensil, and an erasing tip at the opposing end of said utensil.

7. A method according to claim 3, wherein whenever there is no coincidence between the intersect point and the characteristic point, the instrument is used as a pointer by exploiting the proximal tip for pointing on the surface

towards the intersection point, and reproducing said intersection point on a display of said surface by a corresponding graphical representation.

8. A method according to claim 3, further comprising directing a light beam from the proximal tip towards the intersection point, while pointing.

9. A method according to claim 2, wherein each transmission point contains a transmitter.

10. A method according to claim 2, wherein each transmission point contains an antenna, into which power is switched from a distal transmitter.

11. A method according to claim 2, wherein the transmitted signal is selected from the following group:

- an RF signal;
- an IR signal;
- an ultrasonic signal.

12. A method according to claim 2, further comprising enabling the movement of the surface and/or the variation of its orientation without affecting the acquired representation by performing the following steps:

a) receiving transmissions from two or more transmission points located on the surface and in any desired spatial orientation;

b) calculating the spatial coordinates of each point on said surface in any location and spatial orientation;

c) obtaining information related to any undesired change in the coordinates of the calculated intersect point caused by relative movement and/or relative change in orientation of said surface; and

d) compensating for said undesired change prior to displaying the graphical representation.

13. A method according to claim 6, wherein discrimination between writing/drawing and erasing operations of the utensil is obtained by performing the following steps:

a) assigning a unique code to the proximal transmission point closest to the writing/drawing tip;

b) assigning a unique code to the distal transmission point closest to the erasing tip;

c) receiving said codes from said proximal and distal transmission points and calculating their spatial coordinates;

d) operating said utensil in its writing/drawing mode whenever the tip closer to said proximal transmission point coincides with the surface; and

e) operating said utensil in its erasing mode whenever the tip closer to said distal transmission point coincides with the surface.

14. A method according to claim 7, further comprising:

a) pointing toward the surface with the proximal tip or with the distal tip, so that the displayed graphical representation of the intersect point coincides with another displayed graphical representation, said another displayed graphical representation being the representation of an object;

b) while keeping said proximal tip or said distal tip directed to said intersect point, emitting a predetermined characteristic signal from one or more transmission point; and

c) receiving said characteristic signal in the set of receivers and in response, selecting said displayed object.

15. A method according to claim 14, further comprising manipulating the graphical representation of the selected object by changing the intersection point.

16. A method according to claim 15, wherein the manipulation comprises mouse operations.

17. A method according to claim 15, wherein the manipulation comprises executing a program linked to the selected object.

18. A method according to claim 12, wherein the spatial coordinates of the intersect point are obtained by calculating the scalar product between a first vector, extending from a selected transmission point on the surface to another transmission point on said surface, and a second vector extending from said selected transmission point on the surface to said intersect point.

19. A method according to claim 2, wherein the spatial coordinates of the intersect point are obtained by performing the following steps:

a) calculating the projections of the first and of the second fixed distances on a first selected two dimensional plane and obtaining a coordinate which corresponds to one dimension of said first selected plane; and

b) calculating the projections of the first and of the second fixed distances on a second selected two dimensional plane and obtaining the two remaining coordinates which correspond to the dimensions of said second selected plane.

20. A method according to claim 2, wherein the data received by the set of receivers is processed and/or displayed at a remote station, linked to said set of receivers via a data link.

21. A method according to claim 20, wherein the remote-station is selected from the following group:

- a fax machine;

- a computer;
- a cellular phone.

22. A method according to claim 20, wherein the data is transferred through the data link is over a telephone line and/or a cellular phone system.

23. A method according to claim 20, wherein the data is transferred through the data link via an E-mail system.

24. A method according to claim 4, further comprising characterizing the handwriting of a specific user operating the writing/drawing utensil, by performing the following steps:

    a) enabling the tip to move along the axis which coincides with the calculated straight line, so that the displacement of said tip corresponds to the force applied by said specific user, against the drawing surface;

    b) calculating in real-time, the coordinates of the characteristic point while writing/drawing on said drawing surface; and

    c) characterizing said specific user by collecting information related to the force applied by said specific user and/or the angle that is formed between the utensil and said drawing surface, while said specific user is writing/drawing.

25. A method according to claim 24, further comprising characterizing said specific user by collecting information related to the kinematic attributes of the utensil while said specific user is writing/drawing.

26. A method according to claim 2, wherein at least one graphical representation is a 3-D representation.

27. A method according to claim 2 or 12, wherein the surface further

comprises a calibration point for improving the accuracy of the graphical representation, the coordinates of which are known.

28. A method according to claim 2, wherein at least one of the aligned transmission points is a virtual point represented by at least two transmission points which are not aligned, calculating the spatial coordinates of said virtual point by receiving signals transmitted from said at least two transmission points by the set of receivers, and processing said signal.

29. A method according to claim 4 or 5, comprising calibrating the location of the tip by performing the following steps:

a) locating at least three transmitters at three different transmission points along the utensil;
b) locating the tip of said utensil at a predetermined calibration point, the spatial coordinates of which are known;
c) calculating the distance of each transmission point from said calibration point by using the received signal from each transmitter; and
d) calculating the spatial coordinates of said tip using the calculated distance of each transmission point, from said calibration point.

30. Apparatus for determining a spatial and/or planar position of a point comprising two or more transmitters essentially positioned along a straight line passing through the point, the position of which it is desired to determine, said point defining a tip.

31. A system for determining a spatial and/or planar position of a point comprising an apparatus as claimed in claim 30, receivers to receive signals transmitted by the transmitters, and computation apparatus to calculate therefrom the position of the tip.

32. A system for acquiring a graphical representation of one or more intersection points between a straight line and a surface having a known location and orientation, comprising:

a) two or more aligned transmission points being in any desired spatial orientation, each transmission point being separated from its neighboring point(s) by a first fixed distance lying substantially along said straight line, said straight line passing through said transmission points;

b) a set of receivers for receiving a signal transmitted from said at least two transmission points;

c) means for processing said signal and for determining the spatial coordinates of at least two transmission points; and

d) means for determining at least one characteristic point being co-linear with said transmission points, and separated from at least one transmission point by a second fixed distance;

e) means for calculating the spatial coordinates of said characteristic point using the spatial coordinates of said at least two transmission points and said second fixed distance;

f) means for determining and/or calculating the spatial representation of said surface;

g) means for calculating the spatial coordinates of said intersect point; and

h) means for displaying a graphical representation of said surface, a first graphical representation indicating coincidence between said intersect point and said characteristic point, and a second and different graphical representation indicating lack of coincidence.

33. A system according to claim 32, comprising an elongated instrument having a tip which represents the location of each characteristic point, the longitudinal axis of which essentially coincides with the calculated straight

line.

34. A system according to claim 32, in which the instrument is used as a utensil that comprises the tip for writing/drawing on the surface, a trace being reproduced on a display by the graphical representation according to the relative movement between said tip and said surface.

35. A system according to claim 33, in which the instrument is used as a utensil that comprises the tip for erasing from the surface, a portion of a drawn trace which is reproduced on a display by the graphical representation, by removing a corresponding portion from said graphical representation according to the relative movement between said tip and said surface.

36. A system according to claims 32 and 33, in which the instrument is used as a utensil that comprises a combination of a writing/drawing tip at one end of said utensil, and an erasing tip at the opposing end of said utensil.

37. A system according to claim 33, in which the instrument is used as a pointer which operates the proximal tip for pointing on the surface towards the intersection point, and for reproducing said intersection point on a display of said surface by a corresponding graphical representation.

38. A system according to claim 37, further comprising a light source for directing a light beam from the proximal tip towards the intersection point, while pointing.

39. A system according to claim 32, comprising a transmitter in each transmission point.

40. A system according to claim 32, comprising an antenna in each

transmission point, and a distal transmitter, and switching circuitry for switching power from said distal transmitter into said antenna.

41. A system according to claim 32, in which the transmitted signal is selected from the following group:

- an RF signal;
- an IR signal;
- an ultrasonic signal.

42. A system according to claim 32, further comprising:

a) two or more transmission points being on the surface and in any desired spatial orientation;

b) means for calculating the spatial coordinates of each point on said surface in any location and spatial orientation;

c) means for calculating a relative movement and/or relative change in orientation of said surface; and

d) circuitry for compensating for said change prior to displaying the graphical representation.

43. A system according to claim 36, further comprising means for discrimination between writing/drawing and erasing operations according to signals received from transmission points being proximal and/or distal to the surface.

44. A system according to claim 37, further comprising means for selecting a displayed object, to the location of which on the surface, the proximal pointing tip is directed.

45. A system according to claim 44, further comprising means for manipulating the graphical representation of the selected object.

46. A system according to claim 45, comprising manipulation means which simulates mouse operations.

47. A system according to claim 45, comprising means for executing a program linked to the selected object.

48. A system according to claim 32, comprising a remote station, linked to said set of receivers via a data link, at which the data received by the set of receivers is processed and/or displayed.

49. A system according to claim 48, in which the remote station remote-station is selected from the following group:
- a fax machine;
- a computer;
- a cellular phone.

50. A system according to claim 48, in which the data is transferred through the data link is over a telephone line and/or a cellular phone system.

51. A system according to claim 48, in which the data is transferred through the data link via an E-mail system.

52. A system according to claim 34, further comprising:

a) dynamic means for enabling the tip to move along the axis which coincides with the calculated straight line, so that the displacement of said tip corresponds to the force applied by said specific user, against the drawing surface;

b) means for calculating in real-time, the coordinates of the characteristic point while writing/drawing on said drawing surface; and

c) means for by collecting information related to the force applied by

said specific user and/or the angle that is formed between the utensil and said drawing surface, while said specific user is writing/drawing.

53. A system according to claim 32, comprising at least one 3-D graphical representation.

54. A system according to claim 32 or 41, further comprising a calibration point with known coordinates on the surface, for improving the accuracy of the graphical representation.

55. A system according to claim 32, comprising at least two transmission points which are not aligned, for representing at least one of the aligned transmission points as a virtual point, and means for calculating the spatial coordinates of said virtual point, means for receiving signals transmitted from said at least two transmission points by the set of receivers, and means for processing said signal.

56. A system according to claim 34 or 35, comprising a utensil having three transmitters located at three different transmission points along said utensil, and a predetermined calibration point with known spatial coordinates for calculating the spatial coordinates of the tip of said utensil by receiving signals transmitted from said transmission points while said tip touches said calibration point.

57. A method for acquiring a graphical representation of one or more intersection points between a calculated straight line and a surface having a known location and orientation, substantially as described and illustrated.

58. A system for acquiring a graphical representation of one or more intersection points between a calculated straight line and a surface having a known location and orientation, substantially as described and illustrated.

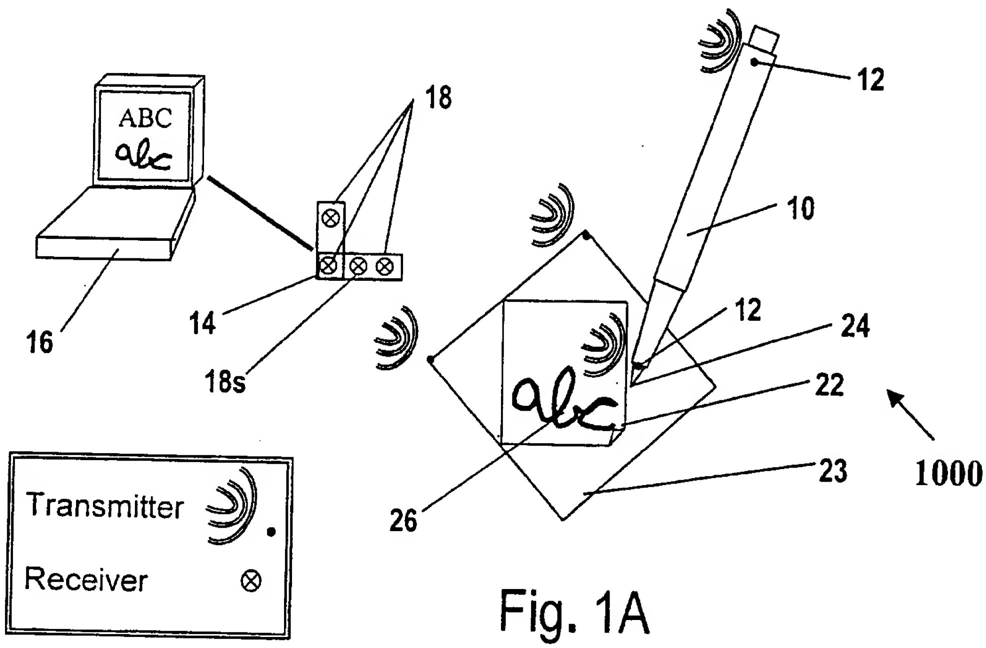

ABC
abc
18
12
10
16
14
18s
12
24
22
23
26
1000
Transmitter
Receiver

Fig. 1A

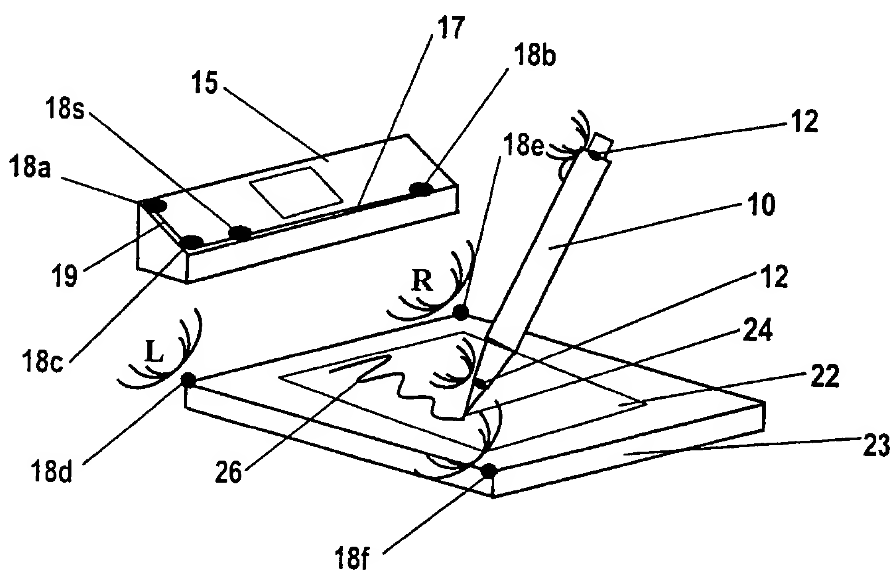

17
18b
15
18s
12
18e
18a
10
19
R
12
24
18c
L
22
18d
26
23
18f

Fig. 1B

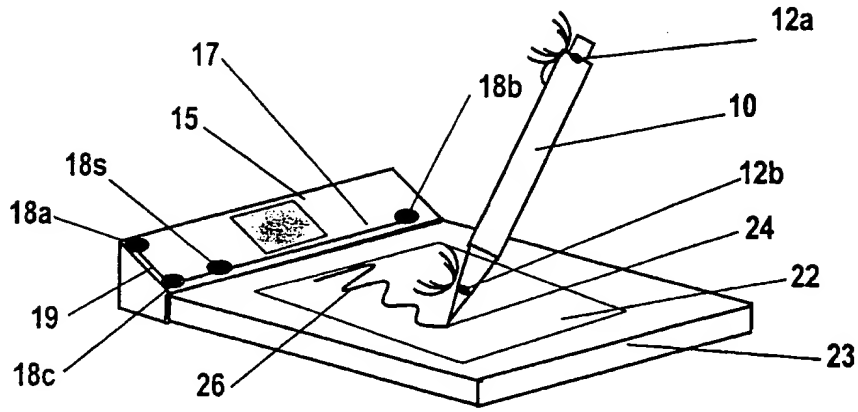

12a
17
18b
10
15
18s
12b
18a
24
22
19
18c
23
26

Fig. 1c

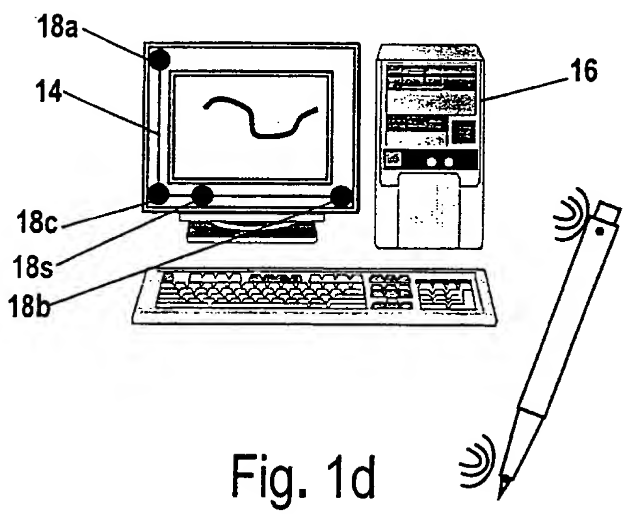

18a
16
14
18c
18s
18b

Fig. 1d

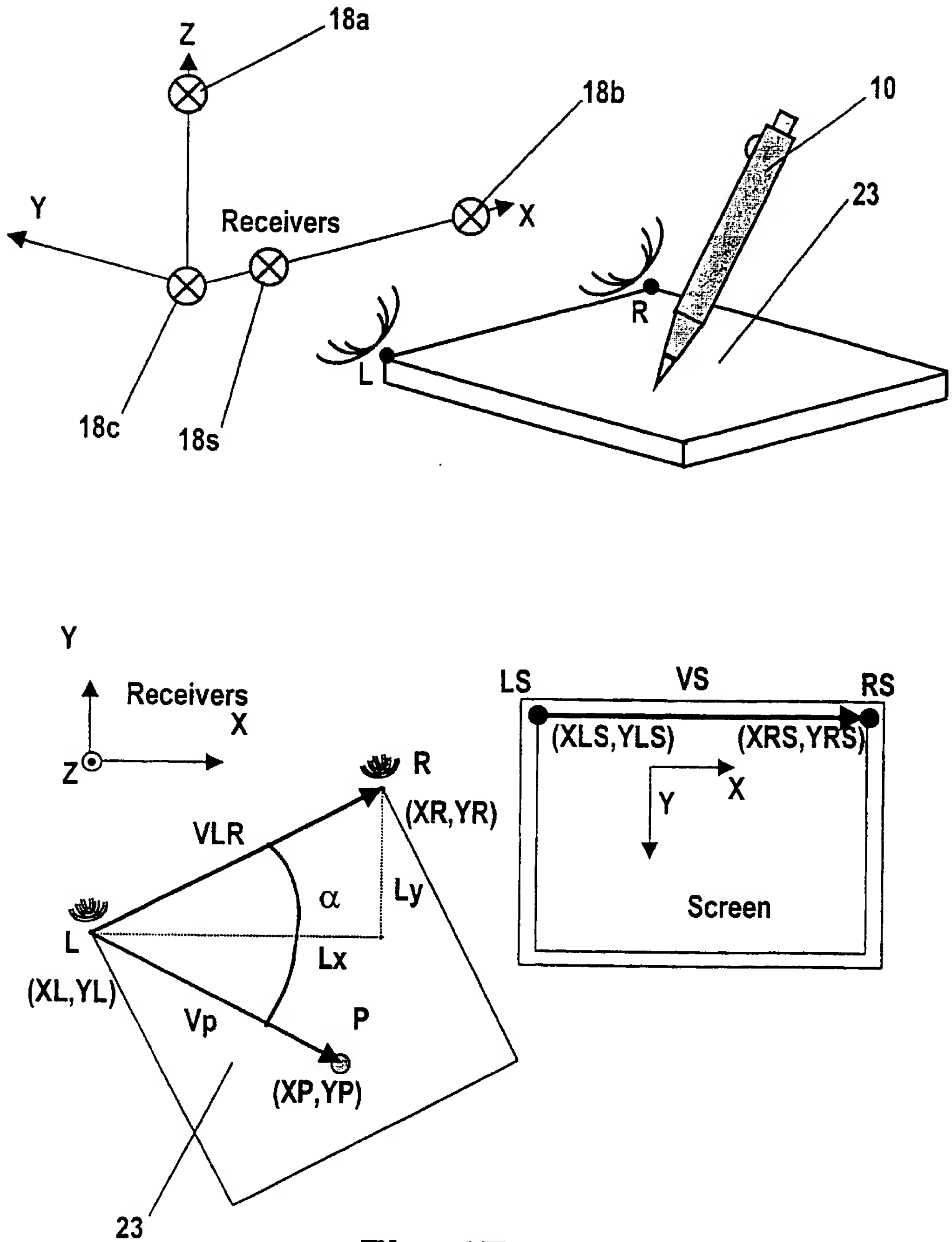

18a
Z
18b
10
Y
Receivers
X
23
R
L
18c
18s
Y
Receivers
X
Z
LS
VS
RS
(XLS,YLS)
(XRS,YRS)
X
Y
Screen
R
(XR,YR)
VLR
α
Ly
L
Lx
(XL,YL)
Vp
P
(XP,YP)
23

Fig. 1E

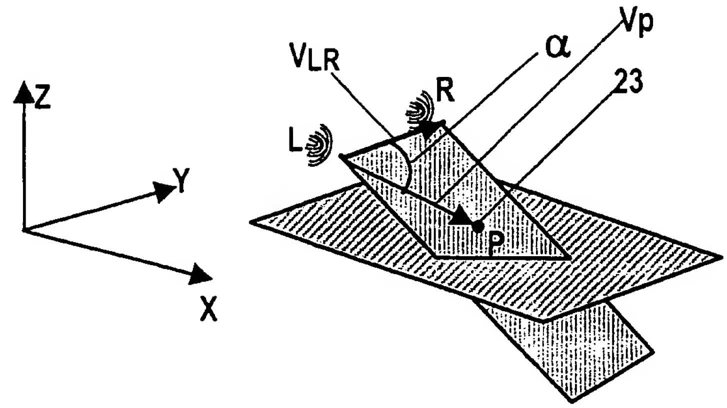


Fig. 1F

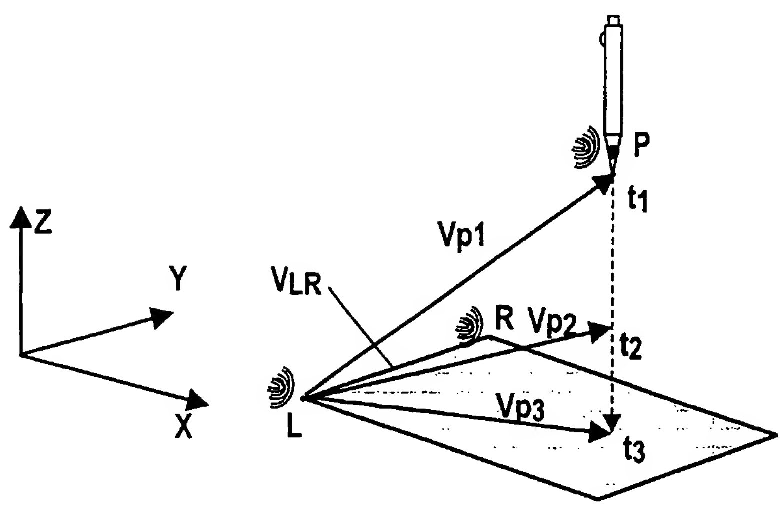


Fig. 1G

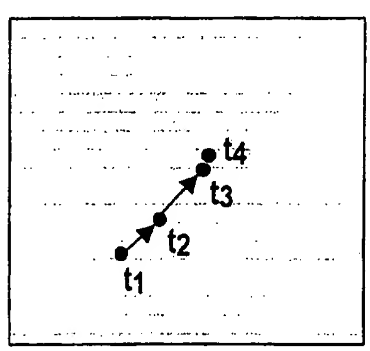


Fig. 1H

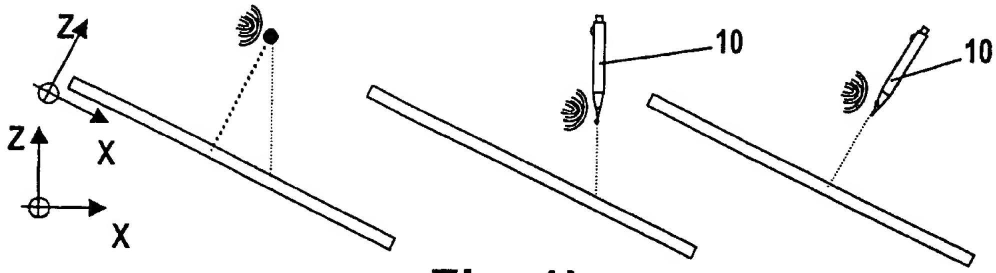


Fig. 1I

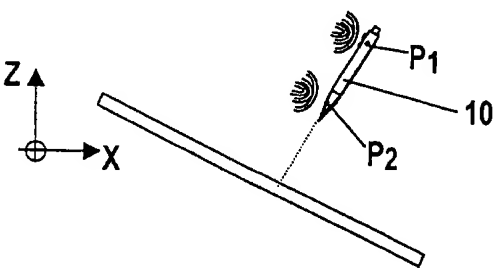


Fig. 1J

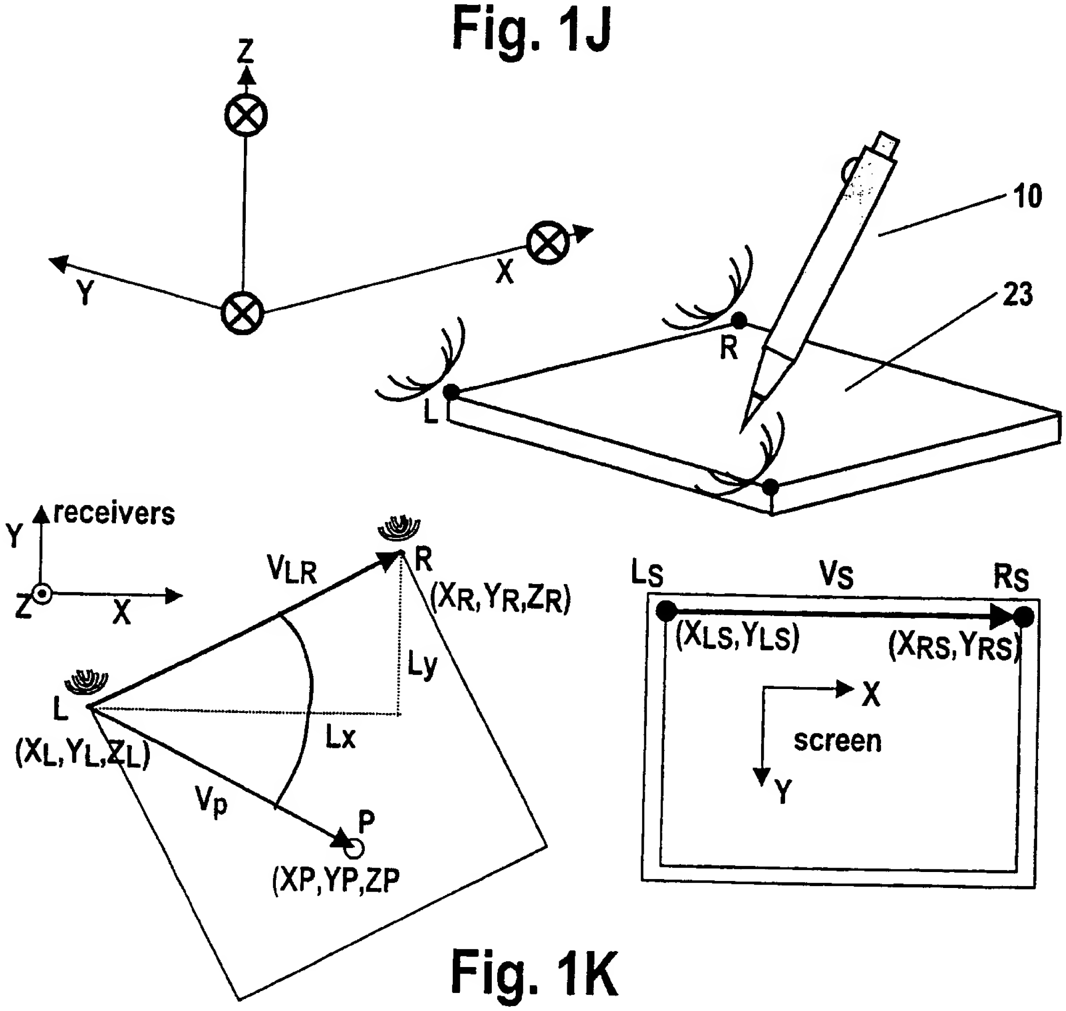


Fig. 1K

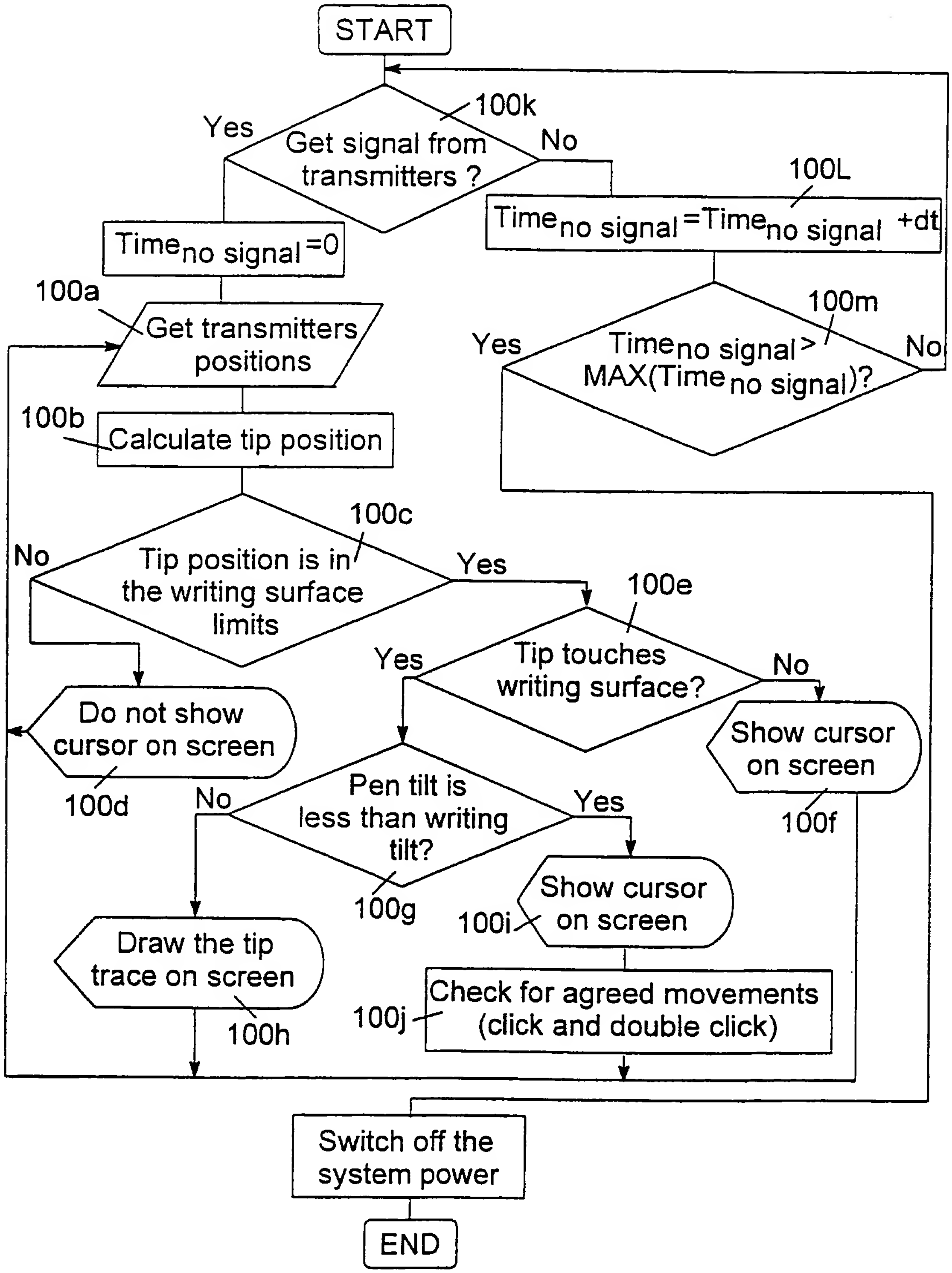

START
Get signal from transmitters ?
100k
Yes
No
100L
Time no signal =Time no signal +dt
Time no signal =0
100a
Get transmitters positions
100m
Yes
Time no signal > MAX(Time no signal)?
No
100b
Calculate tip position
100c
No
Tip position is in the writing surface limits
Yes
100e
Yes
Tip touches writing surface?
No
Do not show cursor on screen
Show cursor on screen
100d
No
Pen tilt is less than writing tilt?
Yes
100f
100g
100i
Show cursor on screen
Draw the tip trace on screen
Check for agreed movements (click and double click)
100j
100h
Switch off the system power
END

Fig. 1L

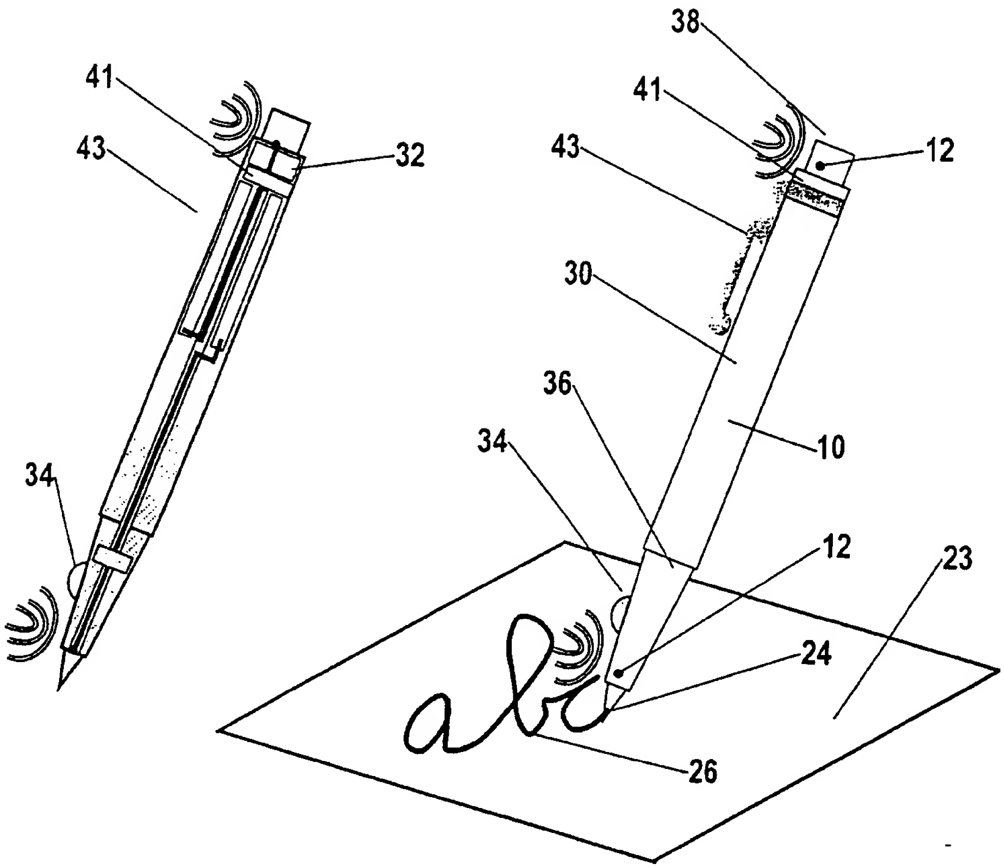


Fig. 2

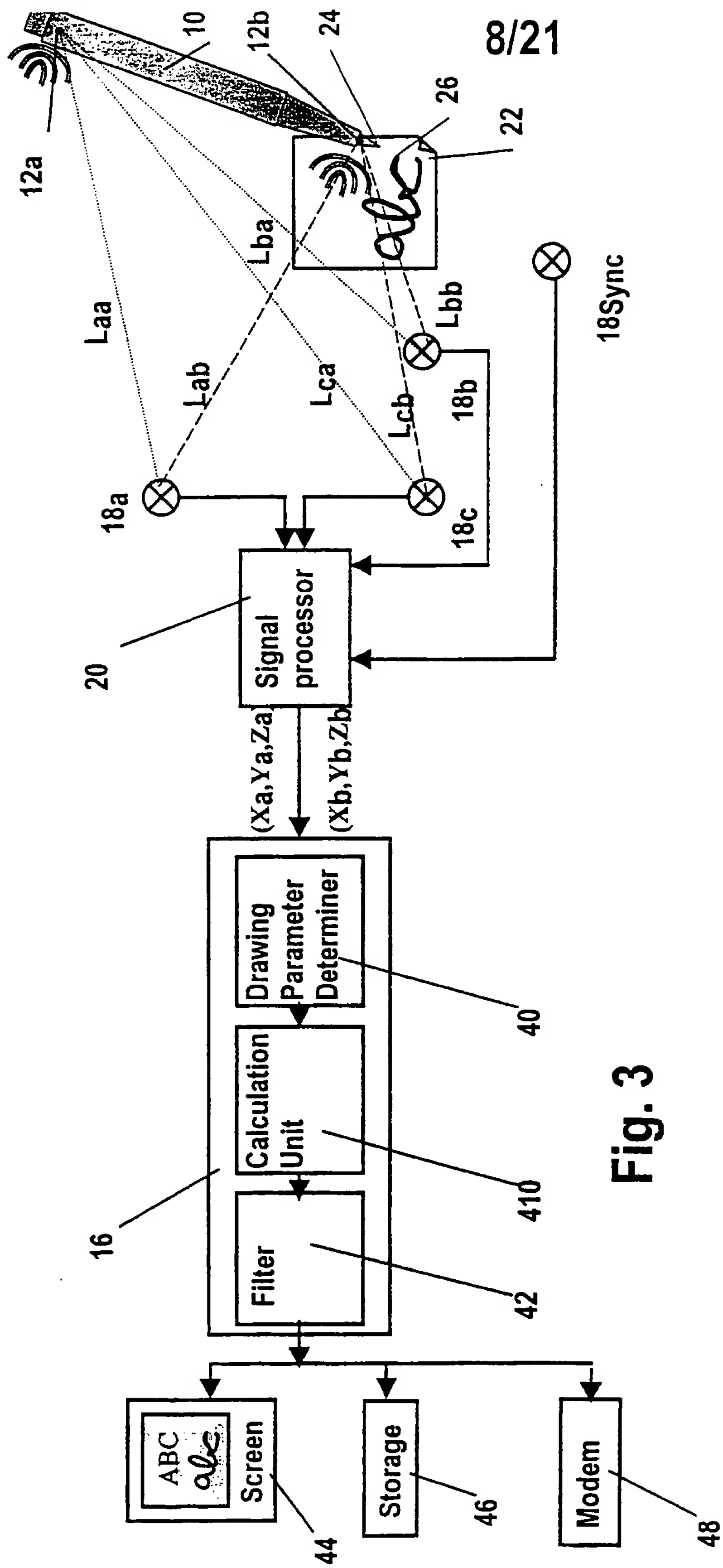

10
12a
12b
24
26
22
Laa
Lab
Lba
Lbb
Lca
Lcb
18a
18b
18c
18Sync
20
Signal processor
(Xa,Ya,Za)
(Xb,Yb,Zb)
Drawing Parameter Determiner
40
Calculation Unit
410
Filter
42
16
ABC
Screen
44
Storage
46
Modem
48

Fig. 3

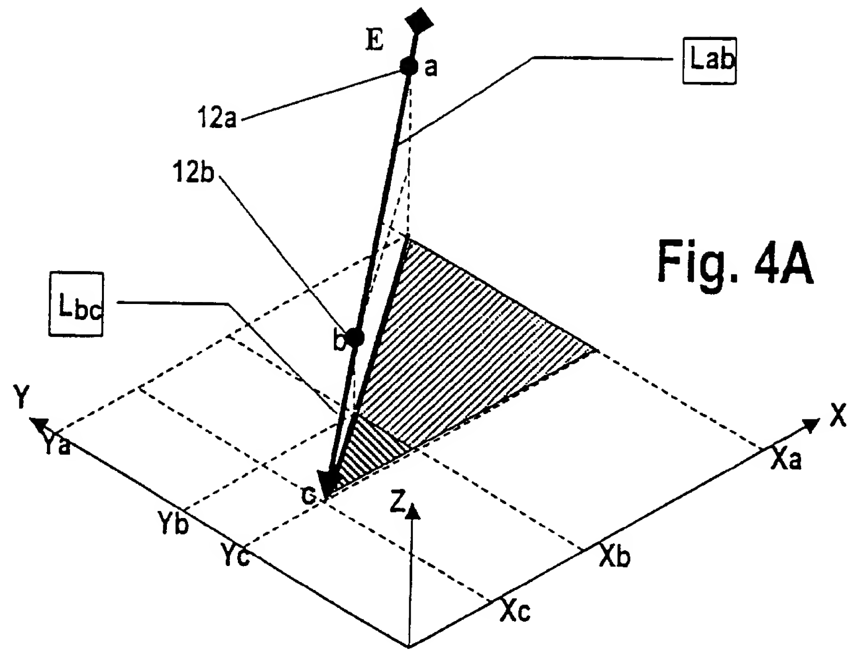


Fig. 4A

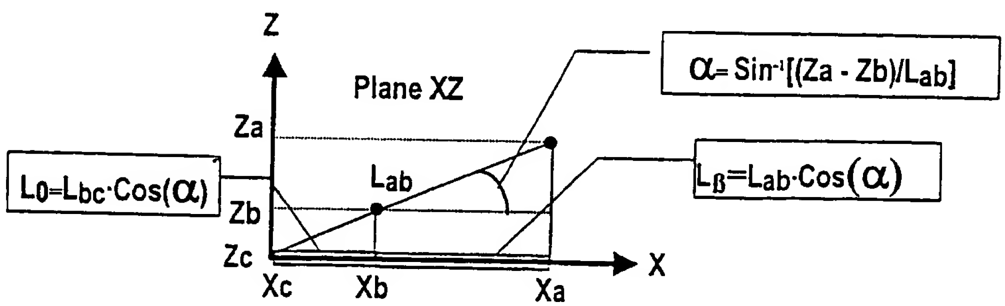


Fig. 4B

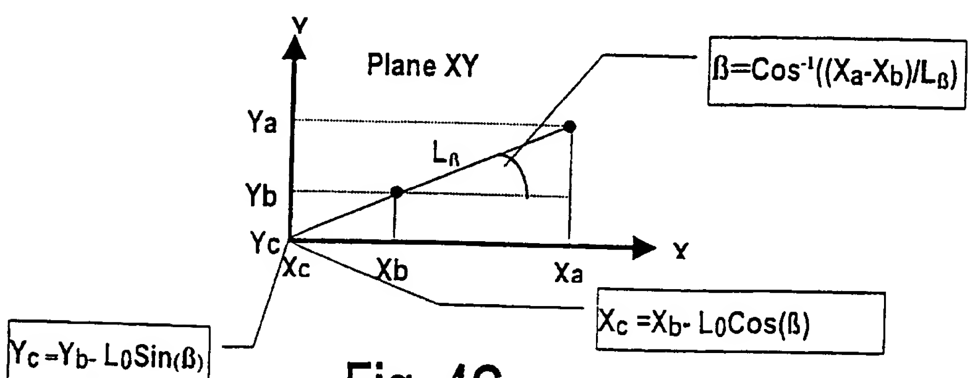


Fig. 4C

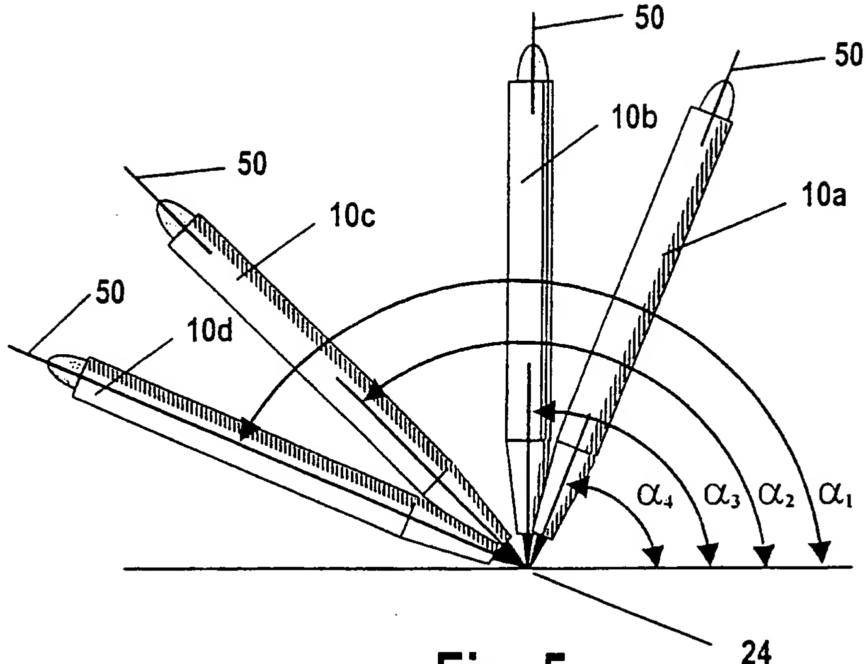


Fig. 5

Fig. 6A

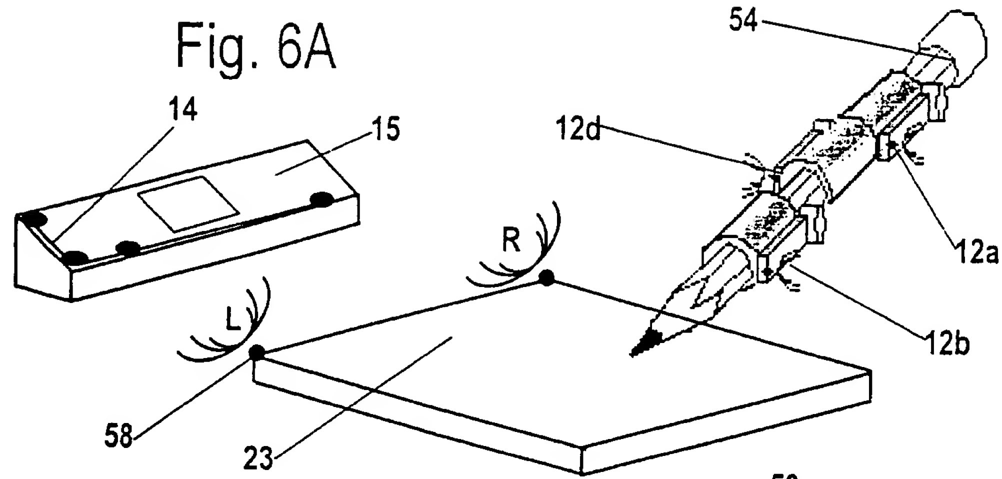


Fig. 6B

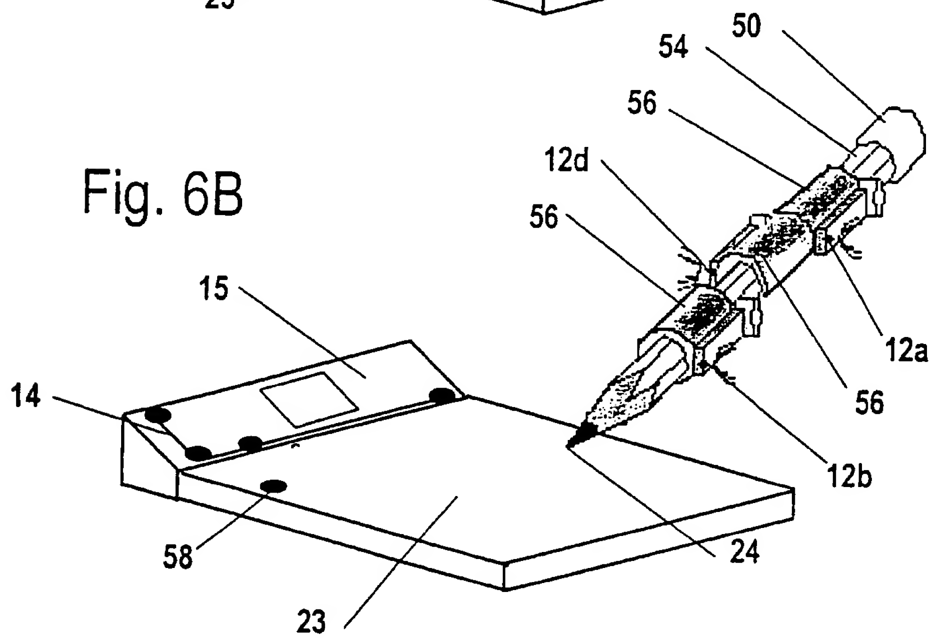
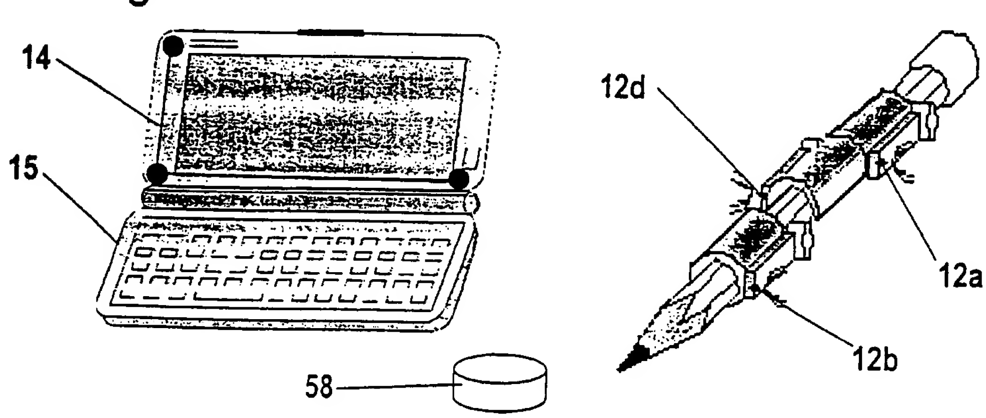


Fig. 6C



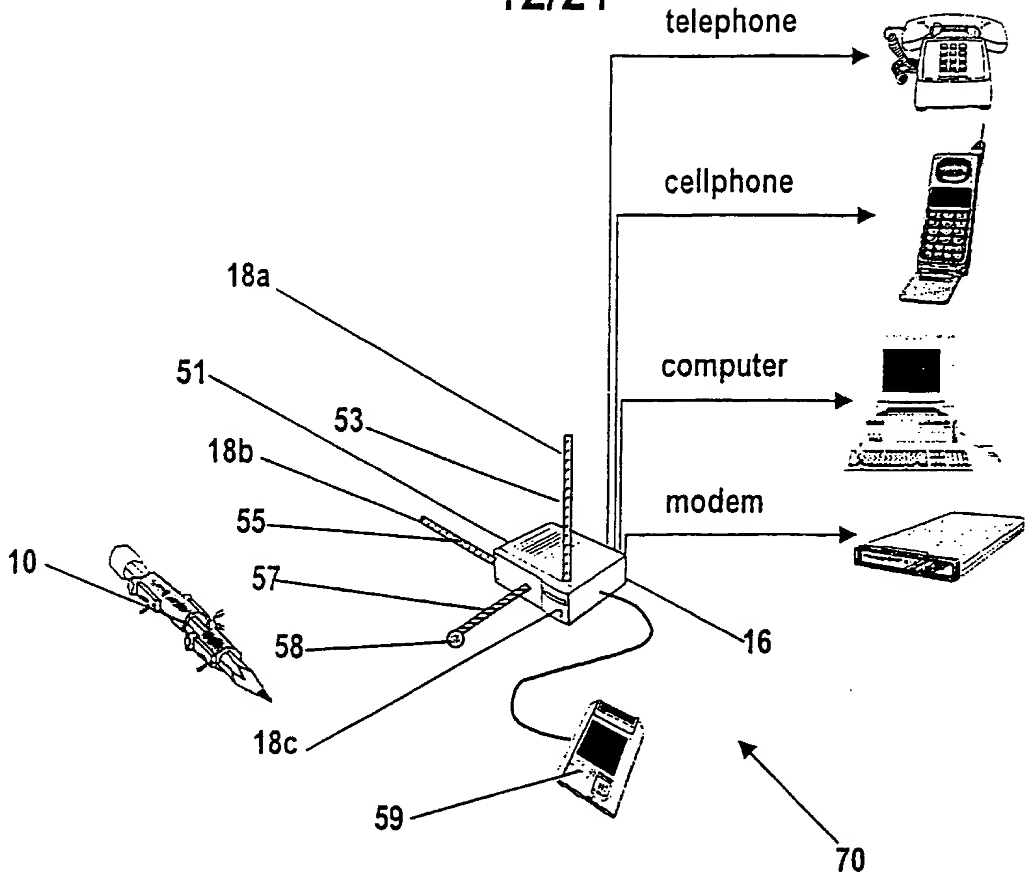

telephone
cellphone
computer
modem
18a
51
53
18b
55
10
57
58
16
18c
59
70

Fig. 7

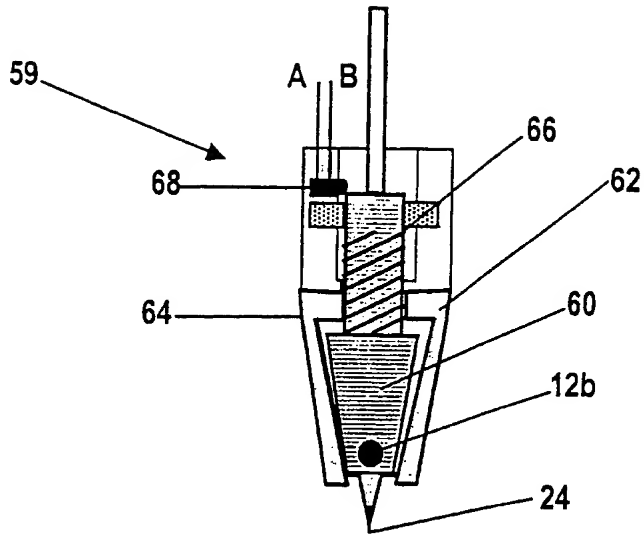

59
A
B
66
68
62
64
60
12b
24

Fig. 8A

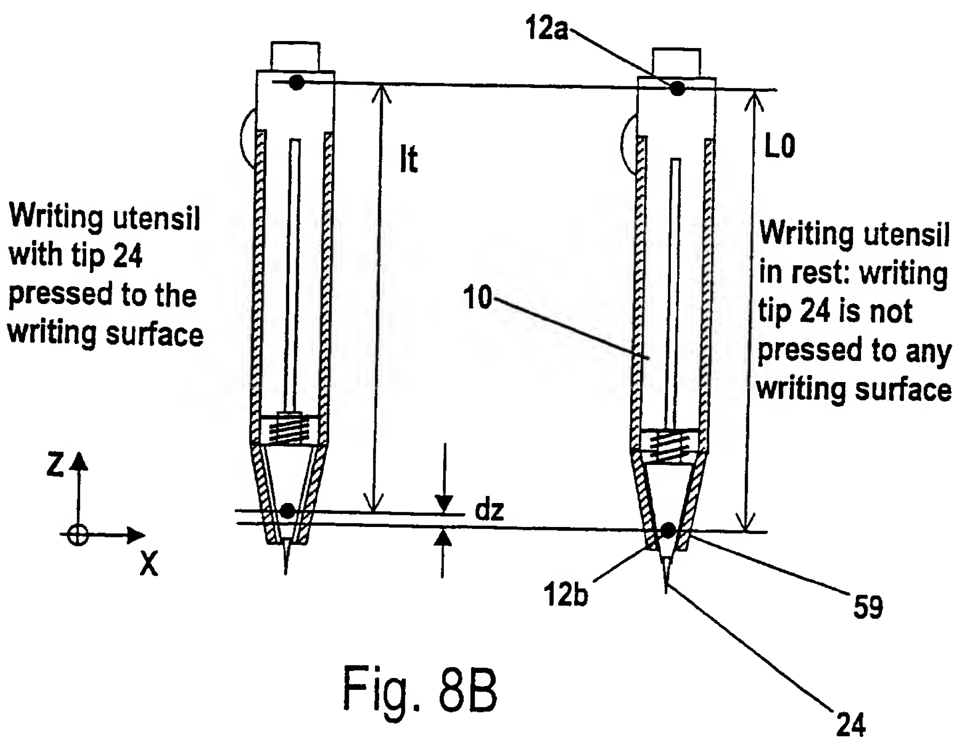

12a
lt
L0
Writing utensil with tip 24 pressed to the writing surface
10
Writing utensil in rest: writing tip 24 is not pressed to any writing surface
Z
X
dz
12b
59
24

Fig. 8B

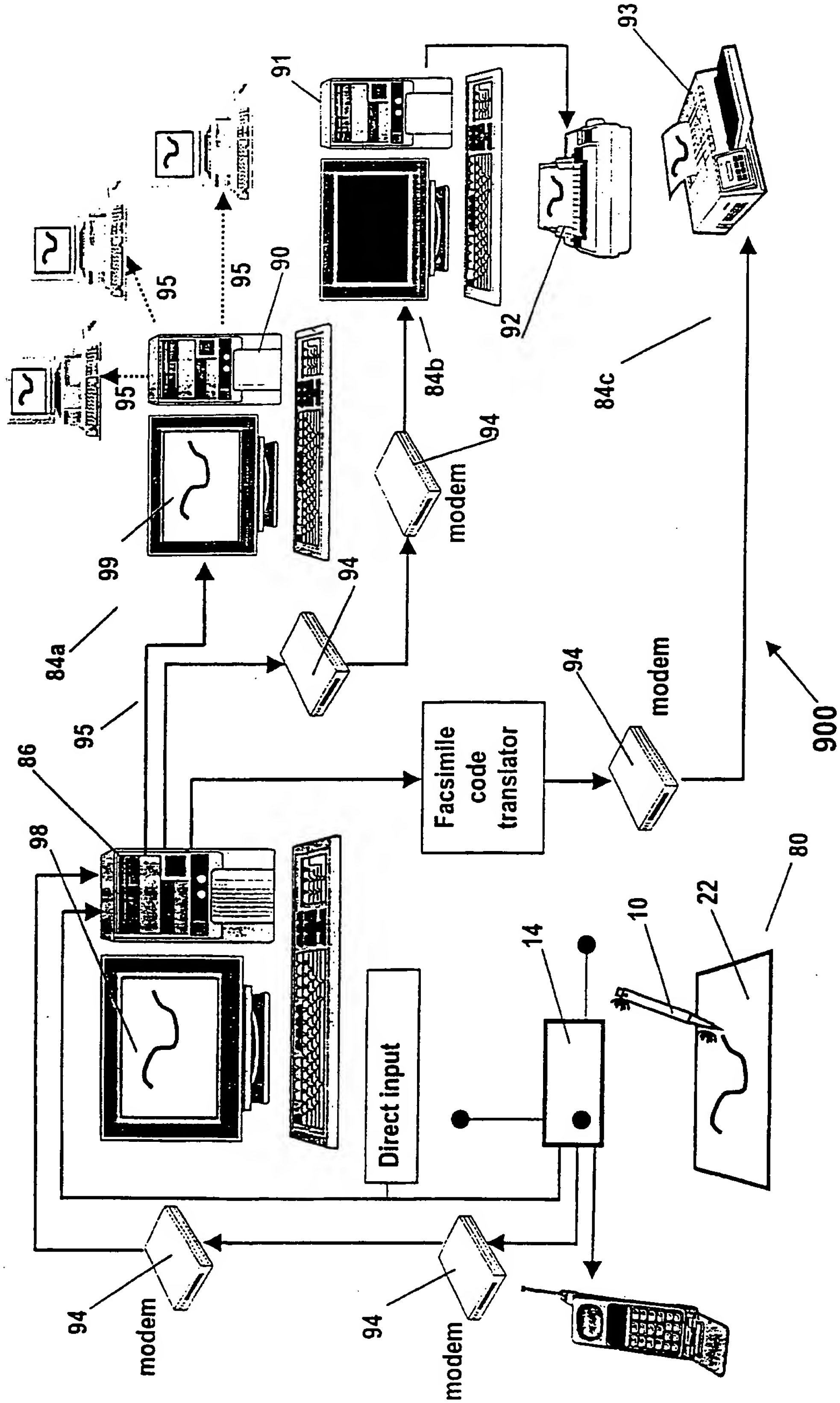

Facsimile code translator
Direct input
modem
modem
modem
modem
84a
84b
84c
86
90
91
92
93
94
95
98
99
10
14
22
80
900

Fig. 9

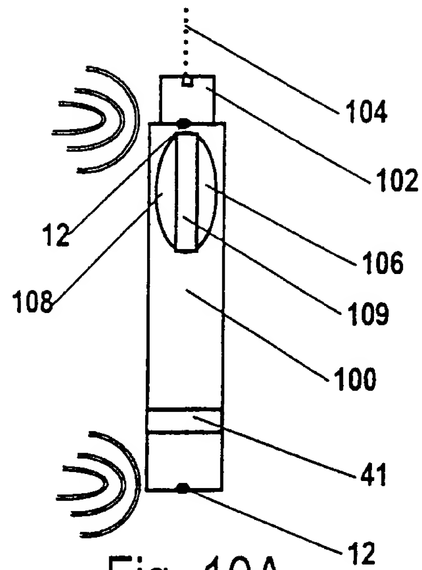


Fig. 10A

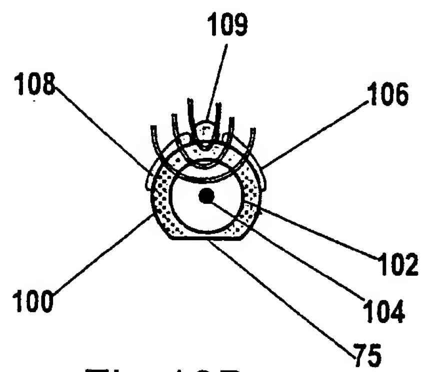


Fig 10B

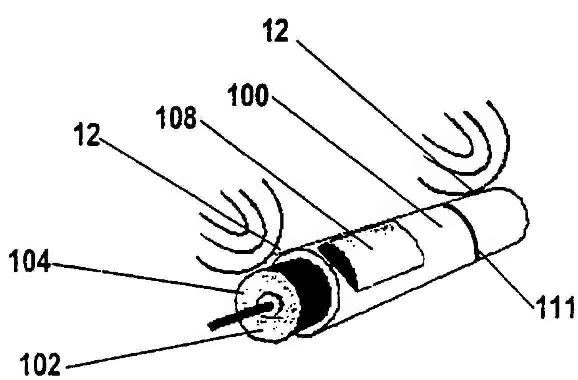


Fig. 10C

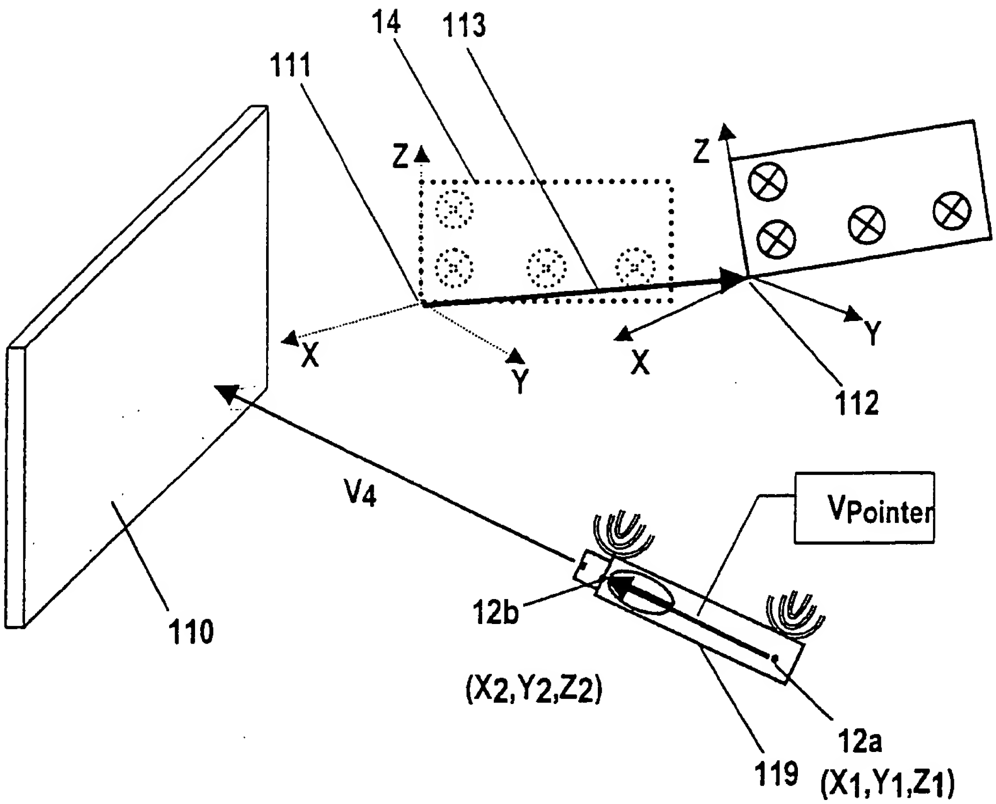

14
113
111
Z
Z
X
Y
X
Y
112
V4
VPointer
12b
110
(X2,Y2,Z2)
12a
119
(X1,Y1,Z1)

Fig. 11A

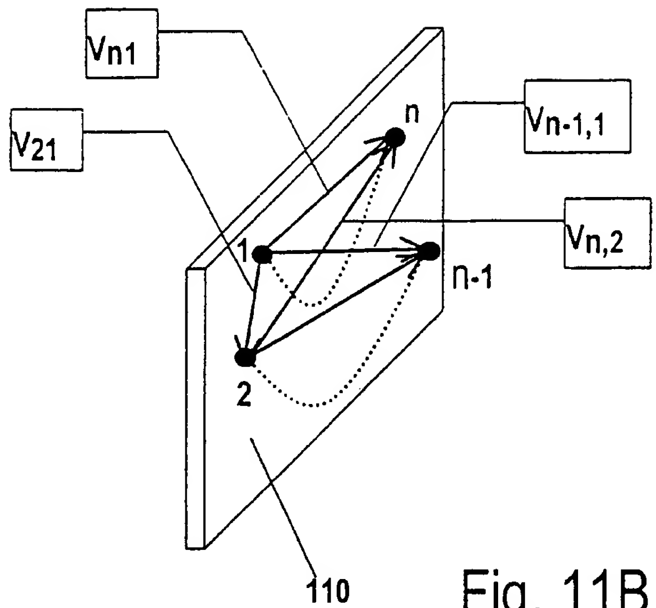


Fig. 11B

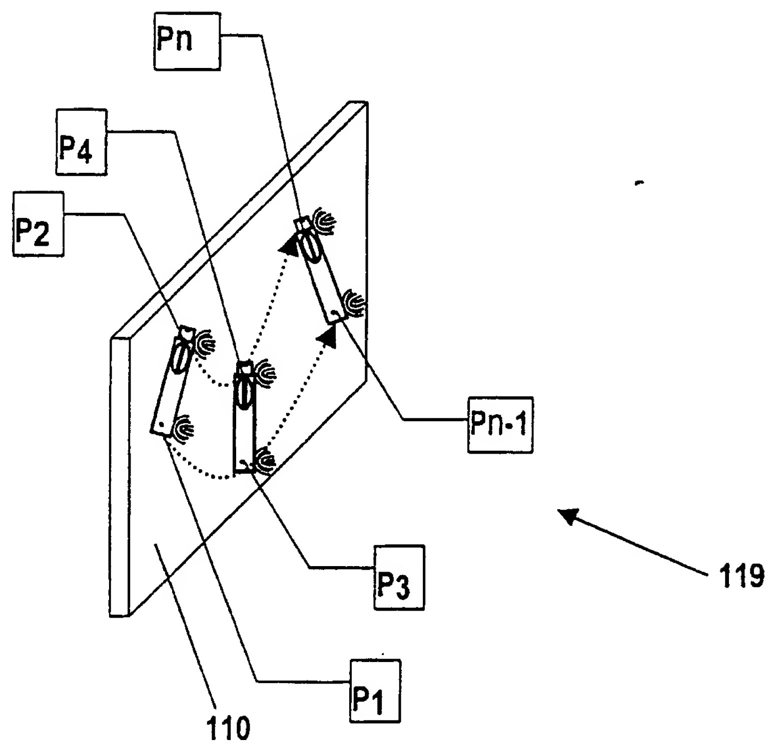


Fig. 11C

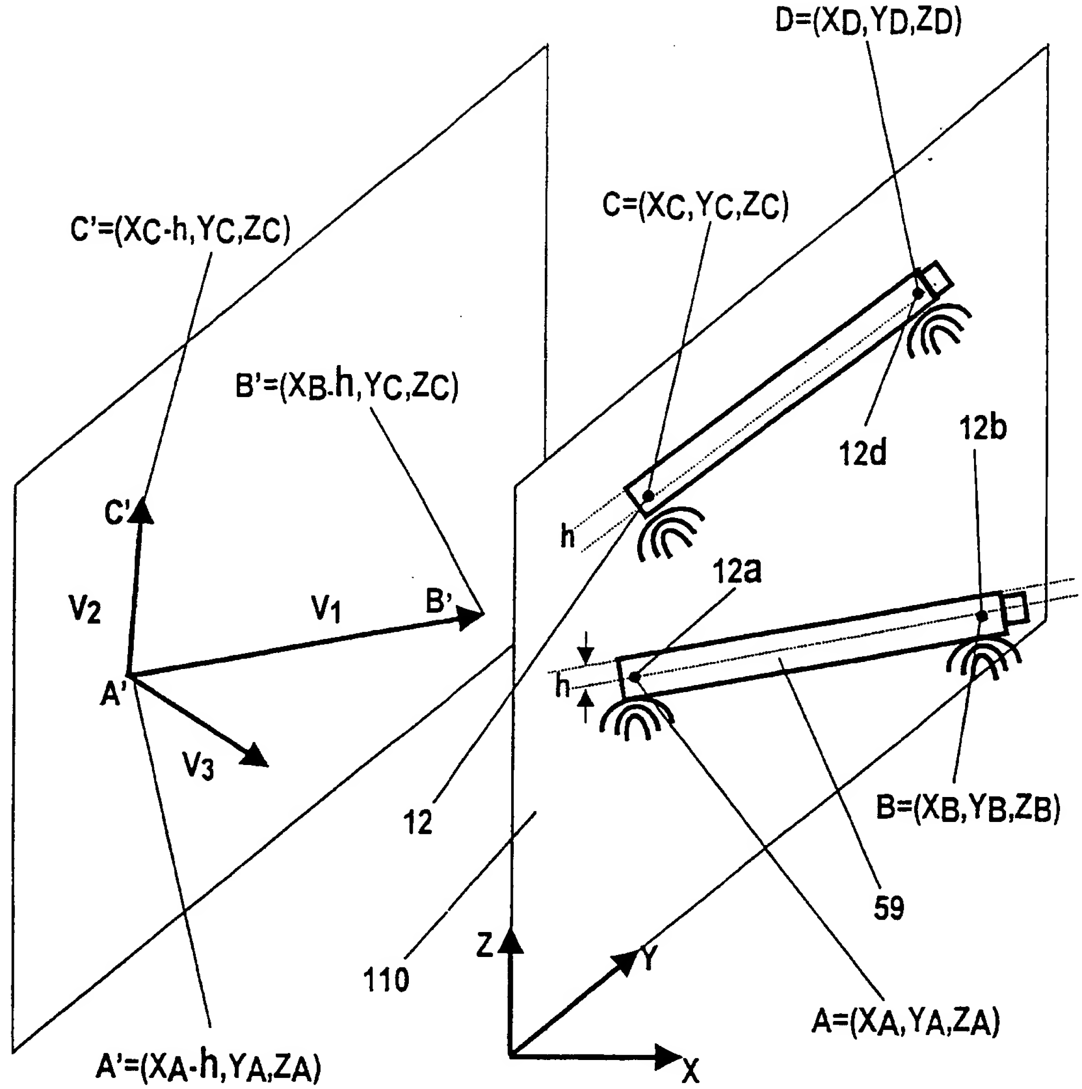

D=(XD,YD,ZD)
C=(XC,YC,ZC)
C'=(XC-h,YC,ZC)
B'=(XB-h,YC,ZC)
12d
12b
C'
h
12a
V2
V1
B'
A'
h
V3
12
B=(XB,YB,ZB)
59
Z
Y
110
A=(XA,YA,ZA)
A'=(XA-h,YA,ZA)
X

Fig. 11D

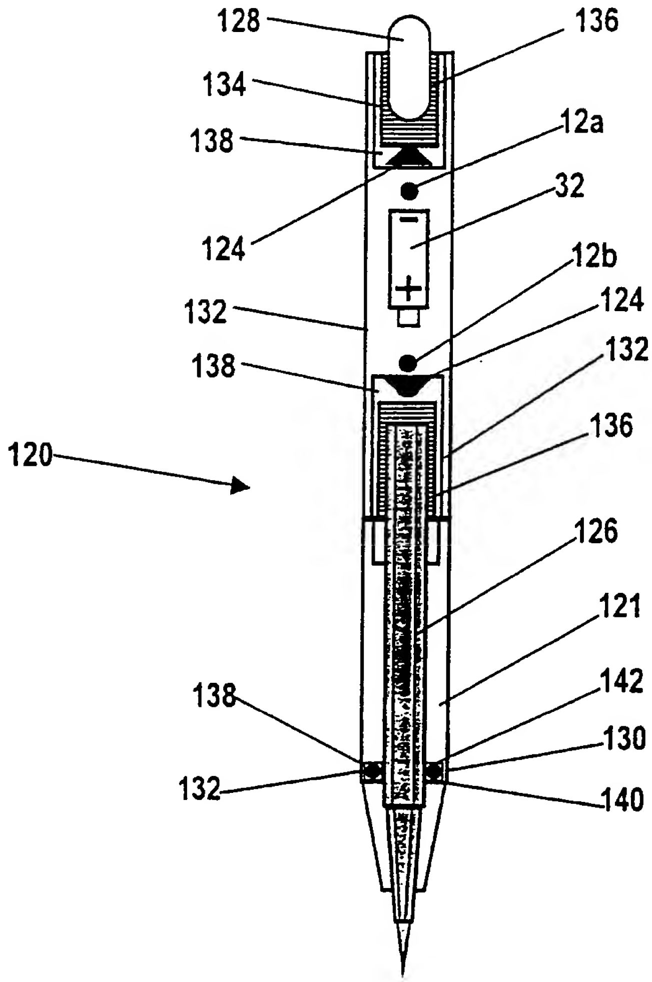

128
136
134
138
12a
32
124
12b
132
124
138
132
136
120
126
121
138
142
130
132
140

Fig. 12

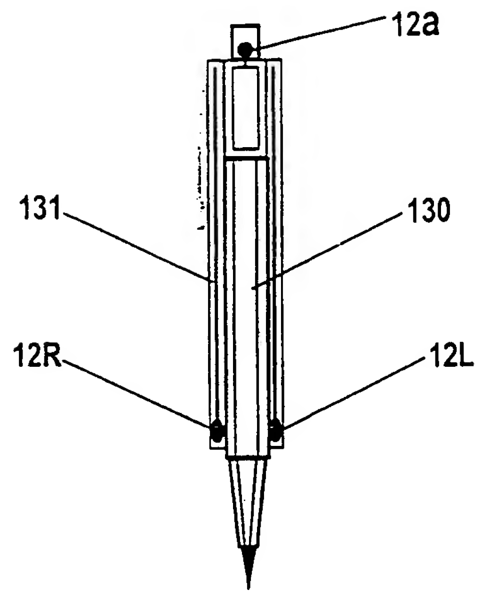


Fig. 13A

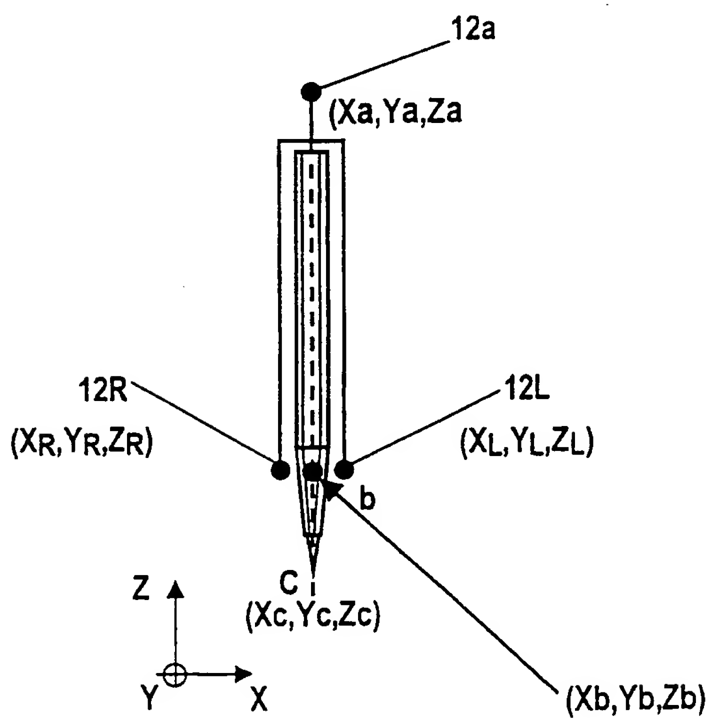


Fig. 13B

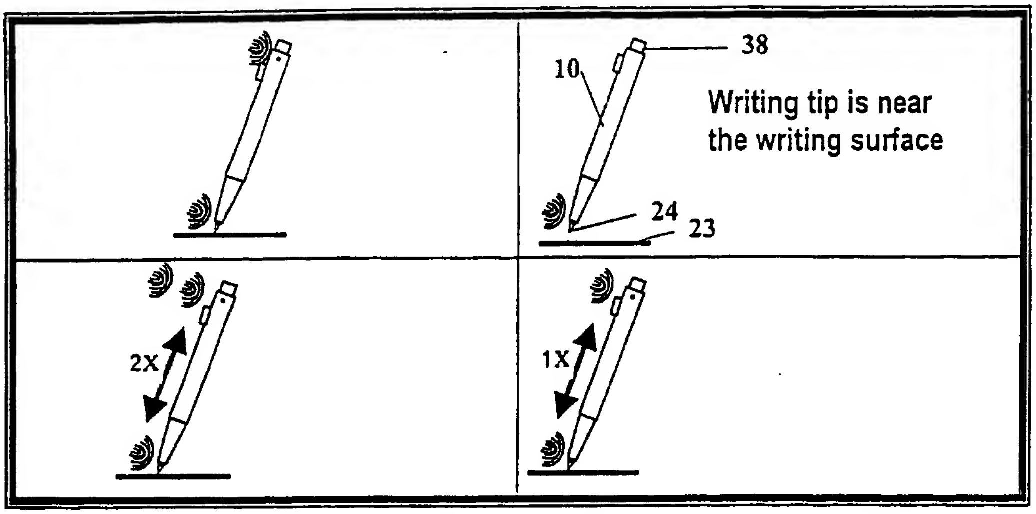


Fig. 14A

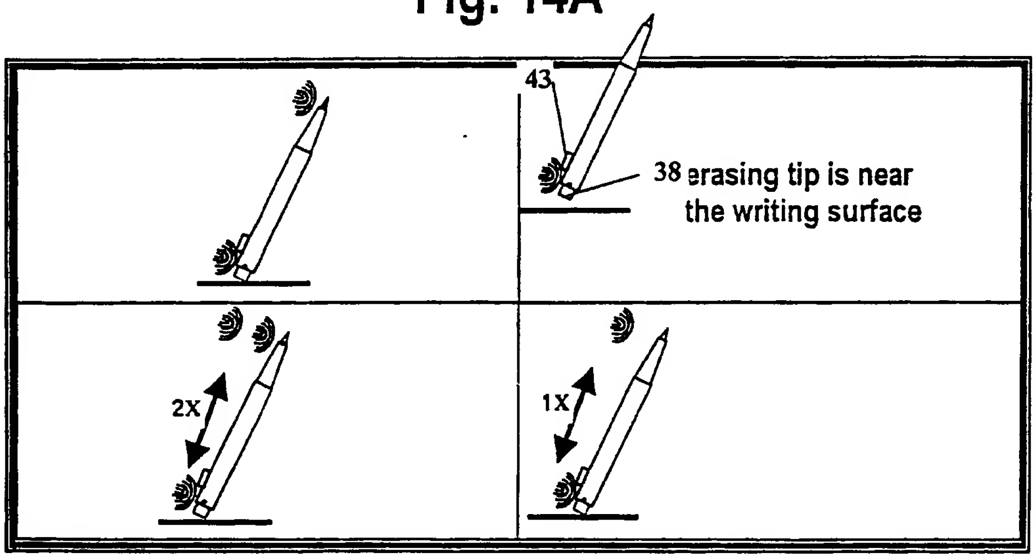


Fig. 14B

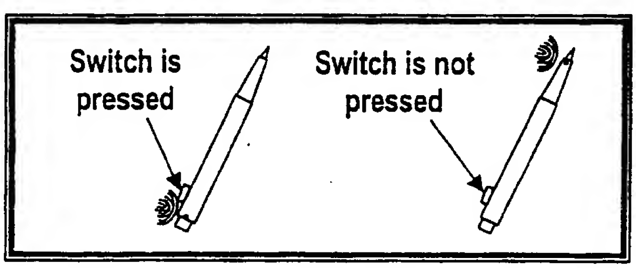


Fig. 14C

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IL 99/00601

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G06K11/18

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G06K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 2 698 191 A (LECTRA SYSTEMES SA) 20 May 1994 (1994-05-20)	1,30,31
Y	page 11, line 19 -page 12, line 7	2,32
A	page 16, line 1 - line 10; figures 1,2,7	3,4,7, 9-11, 14-17, 24,33, 34,37, 39-41, 44-47,52
Y	EP 0 445 906 A (SONY CORP) 11 September 1991 (1991-09-11) column 6, last paragraph; figure 2	2,32

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 April 2000	27.04.00

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Durand, J

1

INTERNATIONAL SEARCH REPORT

Intern nal Application No
PCT/IL 99/00601

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2 018 427 A (PHILIPS NV) 17 October 1979 (1979-10-17)	1,30,31
A	the whole document	2,3, 9-11,33, 34,39-41
A	US 4 991 148 A (GILCHRIST IAN R) 5 February 1991 (1991-02-05)	1-3, 9-11,26, 27, 30-33, 39-41, 53,54
	column 3, line 44 -column 4, line 35; figures 1,2,13	
A	POUPYREV I ET AL: "VIRTUAL NOTEPAD: HANDWRITING IN IMMERSIVE VR" IEEE VIRTUAL REALITY ANNUAL INTERNATIONAL SYMPOSIUM,US,LOS ALAMITOS, CA: IEEE COMPUTER SOC, vol. CONF. 5, 1998, pages 126-132, XP000799821 ISBN: 0-7803-4782-X page 127, left-hand column, paragraph 3.1 -page 128, left-hand column, last paragraph; figures 1-3	2-6,12, 13, 32-36, 42,43
A	EP 0 798 659 A (SYMBIOS LOGIC INC) 1 October 1997 (1997-10-01) column 4, last paragraph; figure 4	8,38
A	WO 94 18663 A (BARON EHUD ;WOLFE EDWARD A (IL); PRISHVIN ALEXANDER (IL)) 18 August 1994 (1994-08-18) page 12, paragraph 2 -page 13, paragraph 1	20-23, 48-51

1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL 99/00601

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 57 58
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
Rule 6.2(a) PCT - Claims refering to other parts of the application

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box I.2

Claims Nos.: 57 58

Rule 6.2(a) PCT - Claims refering to other parts of the application

The applicant's attention is drawn to the fact that claims, or parts of claims, relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure.

INTERNATIONAL SEARCH REPORT

Information on patent family members

Intern nal Application No
PCT/IL 99/00601

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
FR 2698191	A	20-05-1994	AT	147874	T	15-02-1997
			CA	2149213	A	26-05-1994
			DE	69307544	D	27-02-1997
			DE	69307544	T	07-08-1997
			EP	0670070	A	06-09-1995
			ES	2097630	T	01-04-1997
			WO	9411844	A	26-05-1994
			JP	9501247	T	04-02-1997
			US	5717168	A	10-02-1998
EP 0445906	A	11-09-1991	JP	3214223	A	19-09-1991
GB 2018427	A	17-10-1979	NL	7803764	A	12-10-1979
			AT	375192	B	10-07-1984
			AT	266979	A	15-11-1983
			DE	2913713	A	11-10-1979
			FR	2423000	A	09-11-1979
			JP	54137921	A	26-10-1979
			US	4246439	A	20-01-1981
US 4991148	A	05-02-1991	CA	2024527	A,C	27-03-1991
			CA	2124180	A	27-03-1991
			CA	2124181	A	27-03-1991
			DE	69030908	D	17-07-1997
			EP	0420500	A	03-04-1991
			JP	3146891	A	21-06-1991
EP 0798659	A	01-10-1997	JP	10031554	A	03-02-1998
WO 9418663	A	18-08-1994	IL	104575	A	10-01-1997
			AU	6130994	A	29-08-1994
			CA	2155189	A	18-08-1994
			CN	1120868	A	17-04-1996
			EP	0681725	A	15-11-1995
			JP	8508354	T	03-09-1996